

7065 $\frac{43}{A}$

13

A
1800

COMPLETE TREATISE

John Strat ON *Rainier*

ELECTRICITY,

IN

THEORY AND PRACTICE,

WITH

ORIGINAL EXPERIMENTS.

By TIBERIUS CAVALLO, F.R.S.

THE THIRD EDITION,

IN TWO VOLUMES,

Containing the PRACTICE of MEDICAL ELECTRICITY,
besides other ADDITIONS and ALTERATIONS.

VOLUME I.

LONDON:

PRINTED FOR C. DILLY, IN THE POULTRY.

M.DCC.LXXXVI.

1609/5001.

COMPLETE EDITION

ELECTRICITY

THEORY AND PRACTICE

WITH

ORIGINAL EXPERIMENTS

BY THOMAS EDISON, F.R.S.

THE THIRD EDITION

IN TWO VOLUMES

Containing the Principles of Magnetic Electricity,
and the Principles of the Dynamo-Electric Machine



VOLUME

LONDON

PRINTED BY C. DILLI, IN THE ROYAL

MCCCLXXV

To

WILLIAM WATSON,

M. D. F. R. S. M. Br. Cur.

THIS

TREATISE

ON

ELECTRICITY

IS,

WITH THE GREATEST RESPECT,

INSCRIBED,

BY HIS

MOST OBEDIENT,

AND MOST HUMBLE SERVANT,

TIBERIUS CAVALLO.

TO
WILLIAM WATSON
M.D. F.R.S. M.B. C.E.

THIS

TRANSIT

OF

THE CITY



WITH THE GREATEST RESPECT

INSCRIBED

BY HIS

MOST OBEIENT

AND MOST HUMBLE SERVANT

TIBERIUS CAVALLO

P R E F A C E.

THE design of the following
Treatise is, to present to the
public a comprehensive view of the
present state of Electricity, reduced
into as small a compass as the na-
ture of the science would admit.
It is divided into four parts, in each
of which are contained such par-
ticulars, as had less connection with
the rest; and the distinct view of
which, it was thought, might be a
means of preventing a confusion of
ideas in the minds of those readers,

who before have not been much
conversant with the subject.

The first part treats of the laws of Electricity only; *i. e.* of such natural laws concerning Electricity, as by innumerable experiments, have been found uniformly true, and are independent on any hypothesis. In this part, the Author has not descended to any particulars, which were not clearly ascertained, or which were inconsiderable; but he has, at the same time, taken care not to omit any thing material, or which seemed to promise future discoveries.

The second part is merely hypothetical; relating not to facts, but to opinions. The great improbability of most of these hypotheses

P R E F A C E. vii

theses determined the Author to render this part of his work as short as possible.

The third part contains the practical branch of Electricity. Here the Author has taken care to insert a description of all the new improvements in the apparatus; which serve to lessen the expence of it, and at the same time, to facilitate the performance of the experiments. As to the experiments themselves; he has chiefly insisted on a few principal ones, which seemed most necessary to illustrate and confirm the laws of Electricity; omitting a great number of others, which he has met with, as they appeared to be only variations of the former. He has however given an account of some others,

viii. P R E F A C E.

which, though not absolutely necessary, seemed very deserving of notice.

The fourth part contains a brief account of the principal experiments, which have been made by the Author himself, in pursuance of what occurred to him in the course of his studies in this branch of philosophy. In this part he has omitted to mention, not only those attempts, which did not produce any considerable effect, but also the innumerable conjectures he formed about them and others, not yet brought to the test of actual observation.

The fifth part contains the practice of Medical Electricity, which was formerly printed by itself.

The

P R E F A C E. ix

The Author takes this opportunity of acknowledging the obligations he is under to several of his ingenious friends, for various experiments, and remarks, communicated by them; and particularly to the late Mr. WILLIAM HENLY, who did as much as laid in his power to inform him of every particular, which he thought would enrich and embellish the work.

It was deemed unnecessary to point out those gentlemen, whose experiments and observations introduced in this work, were before well known to the world; for which reason the Author has confined himself to the mention of the names of those persons, whose experiments were new, or not commonly

PREFACE.

monly noticed by the writers on this subject.

This third edition is enriched by various interesting particulars in various parts of the work, and especially in the appendix, which contains many articles entirely new.

To render the Treatise more intelligible and useful, five copper-plates are added to it; and a copious index of the particulars which are most deserving of attention.

THE
INVENT OFFICE
LIBRARY

CONTENTS.

VOLUME I.

PART I.

FUNDAMENTAL LAWS OF ELECTRICITY.

CHAPTER

I. CONTAINING the Explanation
of some Terms principally used in
Electricity page 1

II. Of Electrics and Conductors 5

III. Of the two Electricities 15

IV. Of the different Methods of exciting
Electrics 24

V. Of communicated Electricity 34

VI. Of Electricity communicated to Elec-
trics 48

VII. Of charged Electrics, or the Leyden
Phial 55

VIII. Of

xii CONTENTS.

CHAP.

VIII. *Of Atmospheric Electricity* page 71

IX. *Advantages derived from Electricity* 77

X. *Containing a compendious View of the principal Properties of Electricity* 97

PART II.

THEORY OF ELECTRICITY.

I. *The Hypothesis of Positive and Negative Electricity* 103

II. *Of the Nature of the Electric Fluid* 112

III. *Of the Nature of Electrics and Conductors* 123

IV. *Of the Place occupied by the Electric Fluid* 126

PART III.

PRACTICAL ELECTRICITY.

I. *Of the electrical Apparatus in general* 133

II. *The Description of some particular Electrical Machines* 154

III. *The*

CONTENTS. xiii

CHAP.

- III. *The particular Description of some
other necessary Parts of the electri-
cal Apparatus* page 168
- IV. *Practical Rules concerning the Use of
the electrical Apparatus, and the
performing of Experiments* 181
- V. *Experiments concerning electric At-
traction and Repulsion* 1190
- VI. *Experiments on electric Light* 219
- VII. *Experiments with the Leyden Pbial* 1245
- VIII. *Experiments with other charged
Electrics* 1284
- IX. *Experiments on the Influence of Points,
and the usefulness of pointed metal-
lic Conductors, to defend Buildings
from the Effects of Lightning* 293
- X. *Experiments with the electrical Bat-
tery* 308
- XI. *Promiscuous Experiments* 321
- XII. *Further Properties of the Leyden Pbial
or charged Electrics* 356

VOLUME

CONTENTS.

VOLUME II.

PART IV.

NEW EXPERIMENTS IN ELECTRICITY.

CHAP. V.

- I. The Construction of the electrical Kite, and other Instruments. Used with it. page 4
- II. Experiments performed with the electrical Kite. 15
- III. Experiments performed with the atmospheric Electrometer, and the Electrometer for the Rain. 40
- IV. Experiments made with the Electrophorus, commonly called a Machine for exhibiting perpetual Electricity. 49
- V. Experiments on Colours. 58
- VI. Promiscuous Experiments. 65
- VII. An Account of some new Experiments in Electricity, with the Description and Use of two new electrical Instruments. 72
- VIII. Experiments concerning the Effects of Electricity in Vacuo. 90

PART V.

CONTENTS.

iv

PART V.

THE PRACTICE OF MEDICAL ELECTRICITY,

CHAP.

- I. General Remarks relating to Medi-
cal Electricity page 105
- II. Directions for the practical Appli-
cation of Electricity for the Cure of
various Diseases 115
- III. Containing the particular Method of
administering Electricity for various
Diseases, and the Account of some
authentic Cases 144

APPENDIX.

Nº

- I. Of the vindicating Electricity 196
- II. Observations upon the Conductors of
Lightning 207
- III. Extract of a Letter from Mr. Arden,
Lecturer in Natural Philosophy 225
- IV. Observations concerning some Proper-
ties of the Electric Fluid 231
- V. Extracts

ORTM

N^o

- V. *Extracts from Mr. Volta's Paper inserted in vol. lxxii. of the Philosophical Transactions, concerning the Capacity of Conductors, a new Method of discovering very small Degrees of Electricity, and the Electricity of the Atmosphere* page 244
- VI. *An Account of a very powerful Electrical Machine, lately constructed for the Museum of Teyler, at Harlem; and of various Experiments made with it.* 273
- VII. *Of the Electric Properties of the Torpedo, Gymnotus Electricus, and Silurus Electricus.* 287

APPENDIX.

- I. *Of the quantity of Electricity* 196
- II. *Observations upon the Conductivity of Lightning* 207
- III. *Extract of a Letter from Mr. Arden. Lectures on Natural Philosophy* 222
- IV. *Observations concerning some Properties of the Electric Fluid* 231
- V. *Extracts*

INTRO-



INTRODUCTION.

AR T S and sciences, like kingdoms and nations, have each in their turn some happy period of glory and splendor, in which they more than ever attract the human attention, and, by casting a stronger light than at other times, become the favourite object and pursuit of the age ; but these periods are soon over, and a few years of lustre and fame are often overbalanced by centuries of oblivion. From undergoing this fate, some sciences are, however, excepted, which, owing to the vast and necessary extent of their use, and to the fruitfulness of their productions, are ever flourishing ; and although once unknown, yet when fame had proclaimed their birth, or published their advancement, they never afterwards declined. Of this kind is Electricity, one of the most pleasing and
b surprising

xviii INTRODUCTION.

surprising among all the branches of natural philosophy that ever were cultivated by man. This science, after it began to shew the extent and generality of its power; after it was known to be one of the greatest agents of nature; remained always in vogue, was profitably cultivated, irremittedly advanced, and is now brought to a state, in which, instead of becoming sterile, it seems further to engage the general attention, and to promise to its followers more munificent rewards. Optics, indeed, shews many enchanting and useful properties, but concerning vision only; Magnetism exhibits the force of attraction, repulsion, and polarity in that substance called a Magnet: but Electricity, containing, as it were, all within its power, alone exhibits the effects of many sciences, combines together different powers, and, by striking the senses in a particular and surprising manner, affords pleasure, and is of use to the ignorant as well as the philosopher, the rich as well as the poor. In Electricity, we are pleased with beholding its penetrating light, exhibited in numberless different forms; we admire its attraction and repulsion, acting
upon

INTRODUCTION. xix

upon every kind of body ; we are surprised by the shock, terrified by the explosion and force of its battery ; but when we consider and examine it as the cause of thunder, lightning, aurora borealis, and other appearances of nature, whose direful effects we can in part imitate, explain, and even avert, we are then involved in a maze, that leaves nothing to contemplate but the inexpressible and permanent idea of admiration and wonder.

The earliest account we have of any known electrical effect, is by the famous antient naturalist THEOPHRASTUS, who flourished about 300 years before the present era. He tells us that *amber* (whose Greek name is *ηλεκτρον*, and from whence the name *Electricity* is derived) as well as the *lyncurium**, has the property of attracting light bodies. This was all that was known of the subject, for about fif-

* It hath been in a manner proved, that the *lyncurium* of THEOPHRASTUS is the very same substance that now goes under the name of *Tourmalin* ; of which we shall have occasion to speak in the course of this Treatise.

xx INTRODUCTION.

teen centuries after THEOPHRASTUS; in which long period we find no mention in history of any person having made any discoveries, nor even any experiments in this branch of philosophy; the science remaining quite in the dark till the time of WM. GILBERT, an English physician, whose work *de magnete*, which contains several electrical experiments, was published in the year 1600; and who, for his discoveries in this new and uncultivated field, may be justly deemed the father of the present Electricity. He observed, that the property of attracting light bodies, after rubbing, was not peculiar to amber, or the *lyncurium*; but that many other bodies possessed it as well as amber. He mentions a great number of those, together with many particulars, which, considering the state of the science at that time, may be deemed truly great and interesting.

After GILBERT, the science advancing, although by small degrees, passed, as it were, from infancy to puerility; many an excellent philosopher undertaking to examine nature in this walk; such was Sir

FRANCIS

INTRODUCTION. xxi

FRANCIS BACON, Mr. BOYLE, OTTO GUERICKE, Sir ISAAC NEWTON, and most of all Mr. HAWKESBEE, a person to whom we are much indebted for many important discoveries, and a real advancement of Electricity. Mr. HAWKESBEE was the first who observed the great electric power of glass; a substance, that, since his time, has been generally used by all Electricians, in preference to any other electric. He first remarked various appearances of the electric light, and the noise accompanied with it, together with a variety of phenomena relating to electric attraction and repulsion.

After Mr. HAWKESBEE, the science of Electricity, however hitherto advanced, remained for about twenty years in a state of quiescence, the attention of philosophers being at that time engaged in other philosophical subjects, which, on account of the new discoveries of the incomparable Sir ISAAC NEWTON, were then greatly in repute. Mr. GREY was the first, after this period of oblivion, to bring the science again to light. He, by his great discoveries,

xxii INTRODUCTION.

ries, re-introduced it to the acquaintance of philosophers, and from him the true flourishing era of Electricity may be said to take its date.

The number of Electricians that hath been daily multiplying since Mr. GREY, the discoveries made, and the use derived from those, till the present time, are matters really worthy of attention, and deserve to be admired by every lover of the sciences, and well-wisher to the human race.

Whoever would make himself acquainted with the particular transactions concerning those advances, should read the elaborate History of Electricity compiled by the learned Dr. PRIESTLEY, a work that will inform him of whatever had been done relative to the subject till its publication. I, for my part, must forbear making any long historical detail; this treatise being intended to give an account of the present state of Electricity, in a methodical manner, and not an history of the same. I shall in general only observe, that although the science

INTRODUCTION. xxiii

science had, through the indefatigable attention of so many ingenious persons, and by the discoveries that were daily produced, excited the curiosity of philosophers, and engaged their attention; yet, as the causes of any thing, whether small or great, known or unknown, are seldom much attended to, if their effects are not striking and singular; so Electricity had, till the year 1746, been studied by none but Philosophers. Its attraction could in part be imitated by a loadstone; its light by a phosphorus; and, in short, nothing contributed to make Electricity the subject of the public attention, and excite a general curiosity, until the capital discovery of the vast accumulation of its power, in what is commonly called the *Leyden phial*, which was accidentally made in the memorable year 1745*. Then, and not till then, the study of Electricity became general, surprised every beholder, and invited to the

* This great discovery was made by Mr. VON KLEIST, Dean of the Cathedral in Comin, - See the third edition of Dr. PRIESTLEY's Hist. of Elect. Per. VIII. Sect. 1.

xxiv INTRODUCTION.

houses of Electricians a greater number of spectators, than were before assembled together to observe any philosophical experiments whatsoever.

Since the time of this discovery, the prodigious number of Electricians, experiments, and new facts that have been daily produced from every corner of Europe, and other parts of the world, is almost incredible. Discoveries crowded upon discoveries; improvements upon improvements; and the science ever since that time went on with so rapid a course, and is now spreading so amazingly fast, that it seems as if the subject would be soon exhausted, and Electricians arrive at an end of their researches; but, however, the *ne plus ultra* is, in all probability, as yet at a great distance, and the young Electrician has a vast field before him, highly deserving his attention, and promising further discoveries, perhaps equally, or more important than those already made.



COMPLETE TREATISE

ELECTRICITY.

PART I.

FUNDAMENTAL LAWS OF ELECTRICITY.

CHAPTER I.

Containing the Explanation of some Terms principally used in Electricity.

IF a person, holding with one of his hands a clean and dry glass tube, rubs it with his other hand, also clean and dry, stroking it alternately upwards and downwards; and after a few strokes, presents to it small light bits of paper, thread, metal,

tal, or any other substance, the rubbed tube will immediately attract them, and after a little time will repel them—presently, attract them again, and so alternately continue this attraction, and repulsion, for a considerable time. If this tube be rubbed in the dark, and, after having been rubbed, a finger be presented to it at the distance of about half an inch, a lucid spark will be seen between the finger and the tube, accompanied with a snapping noise; the finger at the same time receiving a push, as if it was from air issuing with violence out of a small pipe.

In this experiment, the attraction, repulsion, sparkling, &c. are the effects of that unknown cause called *Electricity*; and hence they are called *electrical appearances*. The glass tube itself is called the *electric*, and all those bodies which are capable by any means to produce such effects, are called *electrics*; and as the rubbing awakes, as it were, in them the power of producing electrical appearances, they are therefore said to be *excited* by the rubbing. The hand, or any other body that rubs an electric,

electric, is called the *rubber*; and if, instead of the person rubbing the glass tube, a machine be constructed capable by any means to excite an electric, this will be an *electrical machine*.

If at the end of the tube opposite to that held by the hand, a wire of any length be tied, suspending a metallic ball at its end, and the tube be excited as before, the metallic ball will, in this case, acquire all the properties of the excited tube, *i. e.* it will attract, sparkle, &c. like the tube itself, the electric virtue passing through the wire to the ball: hence, the wire is said to be a *conductor* of electricity; and all such bodies as are capable to transmit the electric virtue, like the above-mentioned wire, are called *conductors*.

But if, instead of the wire, a silk string be used in the above experiment, and the tube be excited as before, the ball in this case will not shew any signs of Electricity; the silk string not permitting the electric virtue to pass from the tube to the ball:

B 2

hence

4 A COMPLETE TREATISE

hence the silk string in this case, and all those substances through which the electric virtue cannot be transmitted, are called *non-conductors*.

A body resting intirely upon non-conductors is said to be *insulated*; so, in the last experiment, the metallic ball was insulated; since it was suspended intirely by the silk string, which is a non-conductor. The bodies which are conductors, and those which are non-conductors of electricity, together with their peculiar properties, as far as they are known, will be plainly laid down in the following chapters.

C H A P. II.

Of Electrics and Conductors.

THE first and principal maxim in Electricity is, that all the known bodies in nature are divided into two classes, viz. Electrics, and Conductors; experiments shewing, that whatever substance is a Conductor of Electricity, cannot be excited, (hence Conductors are also called *non-electrics*); and that whatever substance can be excited, is not a Conductor, (hence *Electrics* and *Non-conductors* become synonymous terms *.) This maxim, however, is not to be considered as strictly true and general; for in reality we know of no substance that may be called a perfect Electric, nor of any, that may be called a perfect Conductor; the Electric virtue finding some resistance in going through the best Conductors, and being in part transmitted through, or over the surface of most, and perhaps all the Electrics. The less per-

* Electrics are often also called *Electrics per se*.

6 A COMPLETE TREATISE

fect Conductor any substance is, the nearer it comes to the nature of an Electric; and, on the other hand, the less perfect Electrics come nearest to the nature of Conductors. The limits of those two classes come so far one within the other, that there are many substances which may be actually excited, and at the same time are pretty good Conductors. If the reader desires to know those ambiguous substances, he must seek for the worst Electrics among the Electrics, and for the worst Conductors among the Conductors, excepting such on which the experiment cannot be tried, as fluids, powders, &c.

The two following lists contain, in general, all the Electrics and Conductors, disposed in the order of their perfection, beginning in each list with the most perfect of their class. In this order, however, the reader must not expect a great exactness; that being impracticable, when substances are set under general articles; and at the same time is of little, if indeed of any use whatever.

ELECTRICS.

ELECTRICS.

Glass, and all vitrifications, even those of metals.

All precious stones, of which the most transparent are generally the best.

All resins*, and resinous compounds.

Amber.

Sulphur.

Baked wood.

All bituminous substances.

Wax.

Silk.

Cotton.

All dry animal substances, as feathers, wool, hair, &c.

Paper.

White sugar, and sugar-candy.

Air.

* Under the name of resins, I would be understood to mean all such consistent, oily, vegetable, productions as are inflammable, and not soluble in water; gum-lac, therefore, and all such substances, improperly called gums, are also meant under this article. See MACQUER's Chemistry, vol. i. chap. 11.

8 A COMPLETE TREATISE

Oils *.

Calces of metals and semi-metals.

The ashes of animal and vegetable substances.

All dry vegetable substances.

All hard stones, of which the hardest are the best.

Many of the above-mentioned substances, and perhaps all those upon which the experiment can be made, when very hot, lose their electric property, and become quite, though not equally good, Conductors; so red-hot glass, melted resin, hot air, baked wood made very hot, &c. become Conductors of electricity. But it is very remarkable, that the focus of a burning-glass is not a Conductor of electricity. It has been observed, that glass, especially the hardest and best vitrified, is often a very bad Electric, sometimes being quite a Conductor. The Abbé Nollet and others have made various experiments relative to this property of glass, but without deter-

* Mr. CIGNA observed electrical attraction and repulsion between conducting substances plunged in oil. NOLLET's Letters, vol. iii. p. 168.

mining intirely the causes which occasion the difference. Glass vessels, made for electrical purposes, are often rendered very good Electrics by use and time, though they might be very bad ones when new. On the other hand, some glass vessels, which had been long used for excitation, have sometimes lost their power almost intirely. I remember to have observed two indisputable instances of this sort.

A glass vessel, out of which the air has been exhausted, on being rubbed, shews no signs of electricity upon its external surface, but all the electric power appears within the vessel *; and a glass tube, or globe, with the air condensed in it, or full of some conducting substance, is incapable of being excited. But a solid stick of glass, of sealing-wax, &c. may be excited.

* Although a glass vessel, exhausted of air, does not shew any signs of electricity without; yet it has been observed, that the electric power of a glass cylinder is the strongest, when the air within it is a little rarefied, viz. somewhat less dense than the external air. See *L'Elettricismo Artificiale* of G. B. BECCARIA, § 411.

CONDUCTORS.

CONDUCTORS.

Gold.
Silver.
Copper.
Brass.
Iron.
Tin.
Quicksilver.
Lead.
Semi-metals.

Ores; of which the best are those that contain the metallic part in the greatest quantity, and come nearest to a metalline state.

Charcoal, made either of animal or of vegetable substances.

The fluids of an animal body.

All fluids, excepting air and oils*.

The effluvia of flaming bodies.

Ice†.

Snow.

* Salt water is a better Conductor than fresh water.

† Mr. ACHARD, being at Berlin, in the month of January 1776, observed, that water froze to the twentieth degree below 0 of Reaumur's thermometer (which

Snow.

Most saline substances, of which the metallic salts are the best.

Stony substances, of which the hardest are the worst.

Smoke.

The vapour of hot water.

Electricity pervades also vacuum, or the absence of air caused by an air-pump, al-

(which answers to the thirteenth degree below 0 of Fahrenheit's scale) was an electric. He tried his experiments in the open air, where he found that a rod of ice two feet long, and two inches thick, was a very imperfect Conductor, when Reaumur's thermometer was at six degrees below 0, and that it would not in the least conduct, when the thermometer was at 20°. By whirling a spheroid of ice in a proper machine, he even electrified the prime conductor, so as to attract, repel, give sparks, &c. The ice that this gentleman made use of, was free from bubbles of air, and quite transparent;—to produce which, he used to set a vessel, containing distilled water, to be frozen, upon the window of a room, which was rather warm with respect to the ambient air; where the water began to freeze on one side of the vessel, while on the other side it was still liquid; in which case, he says that the bubbles of air separated from the part of the water that began to freeze first, and passed gradually into the liquid part, so as to leave a considerable thickness of ice quite transparent.

most

12 A COMPLETE TREATISE

most as freely as the substance of a good Conductor*.

Besides these, all bodies, in which more or less of some of the above-mentioned Conductors are contained, are also proportionably Conductors; thus, green vegetables, raw meat, &c. are Conductors, on account of the fluids they contain.

From this principle it follows, that all Electrics, before excitation, should be well cleaned, dried, and some made even very hot, in order to free them from every humidity; otherwise they are so far from the nature of Electrics, that they become actually Conductors, on account of the

* “ I beg leave to mention in this place, as favourable to this hypothesis, a most curious discovery made very lately by Mr. WALSH; who, being assisted by Mr. de LUC to make a more perfect vacuum in the double or arched barometer, by boiling the quicksilver in the tube, found that the electric spark or shock would no more pass through it, than through a stick of solid glass.—Dr. PRIESTLY’s Exp. and Obs. on different Kinds of Air, vol. i. p. 284. Farther experiments and observations of the author and others, concerning the conducting or non-conducting power of a vacuum, will be found towards the end of this Work.

moisture

moisture which they contain within their pores, or upon their surfaces.

In regard to the conducting power of charcoal, it must be observed, that all charcoal will not conduct equally well, there being some that will hardly conduct at all; and sometimes is in such a state, that it will assist the passage of a large quantity of electric fluid along its surface, when it will not conduct it any other way. This difference, however, is not occasioned by the difference of the wood from which the coals are made, but by the degree of heat that is applied in the process of making them; the best Conductors being such as have been exposed to the greatest heat*.

Whether the piece of wood in the process of coaling is suffered to flame, or not, is quite immaterial; and the continuance of the same degree of heat has no apparent effect with respect to the conducting power of the charcoal.

* See Dr. PRIESTLEY's second volume of Observations on different Kinds of Air, Sec. xiv.

14 A COMPLETE TREATISE

It will not be improper to observe in this place, the different changes from Conductor to Non-conductor, occasioned in the same substance by different preparations. A piece of wood just cut from a tree is a good Conductor; let it be baked, and it becomes an Electric; burn it to a coal, and it is a good Conductor again; lastly, let this coal be reduced to ashes, and these will be impervious to electricity. Such changes are also observable in many other bodies; and very likely in all substances there is a gradation from the best Conductors to the best Non-conductors of Electricity.

C H A P. III.

Of the two Electricities.

IF, in the experiment mentioned in the first chapter, the person that rubs the tube be insulated, i. e. be set with his feet upon a cake of resin, a stool with glass feet, or any other good Electric, so that the communication between his body and the earth be cut off by means of Electrics; and if in this situation he rubs the tube with his hand, as before; this person, as well as the tube, will, in this case, appear electrified. If any light bodies be presented to any part of his body, they will be attracted and repelled. If another person presents his finger to him, a lucid spark will follow, with a snapping noise; and, in short, this insulated person will shew every sign of electricity that the tube exhibits. But their electricities are not the same; the electricity of the tube being just the reverse of the electricity of the person: and their particular appearances are the following:

1. Whenever

16 A COMPLETE TREATISE

1. Whenever a light body insulated, as, for instance, a small piece of cork suspended by a silk thread, has been attracted by the tube, and afterwards repelled, if no conducting substance touches it in this state of repulsion, it will not be attracted by the tube again. The same happens with the insulated person; for when this light body has been once attracted by any part of his body, and afterwards repelled, it will not be attracted again; but if in this state of repulsion the tube be presented to it, then it will be attracted, and that violently, by the tube; and when repelled by the tube, it will be attracted by the insulated person. Further, if two or more light insulated bodies, like the above-mentioned piece of cork, be severally attracted by the tube, and when afterwards repelled, be brought within a small distance of one another, they will repel each other, and, if well insulated, continue in this electrified and repulsive state for a considerable time. The same will happen, if they are presented to the person instead of the tube; they will also, after being once repelled by this, repel one another. But, if

if one, or more of those light insulated bodies be attracted and repelled by the tube; and one or more others be attracted and repelled by the person, and afterwards both or all (*i. e.* such as were presented to the tube, and such as were presented to the insulated person) be brought within a sufficient distance of one another, they will then, instead of repelling, attract each other; and instead of continuing electrified, extinguish at once every sign of electricity. These two electricities, therefore, are (as was said before) the one just the contrary of the other, the one attracting what the other repels; and, as if one was an affirmative, and the other a negative power, when equal quantities of each are summed together, they balance each other, and lose every property.

2. Another characteristic of each of the two electricities, consists in the appearance of their light. If a pointed body, as a needle, a wire, or the like, be presented to the excited tube in the dark, a lucid globule, like a star, will be seen upon the point; but if this pointed body be presented to the insulated person, then in the

C

place

place of the star a lucid pencil appears, composed of rays, seemingly issuing from the point, and diverging towards the person *.

3. Lastly, in some experiments (which will be hereafter particularly mentioned, and this property better explained) the electricity of the tube, when in the act of passing from a body overcharged with it to another, either not electrified, or possessed of the contrary electricity, shews an indisputable current from the former to the latter; and the electricity of the insulated person, when in the act of passing from a body overcharged with it to another, either not electrified, or possessed of the contrary electricity, shews clearly a current from the latter to the former.

These two electricities are not only observed in the above-mentioned experiment, but in several other cases also; and they always accompany each other; for when

* This pencil of rays will appear better, if a pointed needle be presented to the insulated person, at the distance of about one inch from some part of his body, while he is actually rubbing the tube in the dark.

different

different Electrics are rubbed, some will acquire one electricity, and others will acquire the contrary; the rubber, if insulated, shewing at the same time signs of the electricity contrary to that acquired by the excited electric: besides this, almost all Electrics may be made to shew at pleasure the one or the other electricity, according to the substance used for a rubber. Hence the following corollaries may be deduced: *viz.* 1. Whenever two different substances (being both insulated, or only that which is a Conductor) are rubbed together, except they are both equally good Conductors, they will be both electrified, and one acquire the electricity contrary to the electricity of the other. 2. Almost all the Electrics may be made to acquire, at pleasure, the one or the other electricity, by using proper rubbers.

The first of these two electricities, *i. e.* that possessed by the glass tube in the above experiment, as it was thought to be the constant production of rubbed glass, was called the *Vitreous Electricity*; and the other, as it was first observed to be produced by, resinous substances, was called

the *Resinous Electricity*. The Vitreous Electricity is also called *Positive* or *Plus Electricity*, for a reason that will be considered in the course of this Treatise; and the Resinous is called also *Negative* or *Minus Electricity*. A body, therefore, possessed of the Vitreous, Positive, or Plus Electricity, is that which shews such signs as the tube was said to exhibit; and a body possessed of the Resinous, Negative, or Minus Electricity, is that which shews such signs as the insulated person was said to exhibit in the above-mentioned experiment.

In the following Table may be seen what Electricity will be excited in different bodies, when rubbed with different substances. Smooth glass, for instance, will be found by this Table to acquire a Positive Electricity, when rubbed with any substance hitherto tried, except the back of a cat (by which I mean the skin of a cat while on the animal alive); rough glass, *viz.* glass the polish of which has been destroyed by emery or otherwise, will be found to acquire the Positive Electricity, when rubbed with dry oiled silk, sulphur, &c. and the Negative, when



when rubbed with woollen cloth, the hand, &c. and so of the rest.

The back of a cat	Positive	{ Every substance with which it has been hitherto tried.
Smooth glass	Positive	{ Every substance hitherto tried, except the back of a cat.
Rough glass	Positive	{ Dry oiled silk, sulphur, metals.
	Negative	{ Woollen cloth, quills, wood, paper, sealing-wax, white-wax, the human hand.
Tourmalin	Positive	{ Amber, air †.
	Negative	{ Diamond, the human hand.
Hare's skin	Positive	{ Metals, silk, loadstone, leather, hand, paper, baked wood.
	Negative	{ Other finer furs.
White silk	Positive	{ Black silk, metals, black cloth.
	Negative	{ Paper, hand, hairs, weasel's skin.
Black silk	Positive	{ Sealing-wax.
	Negative	{ Hare's, weasel's, and ferret's skin, loadstone, brass, silver, iron, hand.
Sealing-wax	Positive	{ Metals.
	Negative	{ Hare's, weasel's, and ferret's skin, hand, leather, woollen cloth, paper.
Baked wood	Positive	{ Silk.
	Negative	{ Flannel.

* Glass may be made rough by rubbing it with sand, or emery.

† i. e. By blowing with a pair of bellows upon it. By this means many Electricians may be sensibly excited, and some better if the air blown is hot; although, in both cases, very little Electricity can be obtained.

The preceding Table might have been much extended, had I chosen to bring into it all the minutiae attending this matter as far as is known; but this I have thought unnecessary and impracticable, because experiments of this kind are of so nice a nature, that they require the most scrupulous attention in making them; and then their effects depend upon so small and variable circumstances, that often the very same Electric, rubbed with the same rubber, gives at one time signs of one Electricity, and at another time signs of the contrary. A very little alteration in the surface, a different degree of dryness, and even a different application of the same substances, often occasions a difference in the Electricity. I shall only observe in general, that as far as may be deduced from the greatest number of experiments, it appears, that when different substances are rubbed together, that whose Electric power is the strongest, in general acquires the Positive, and the other the Negative Electricity; and when two bodies, differing in the smoothness or roughness of their surfaces, are rubbed together, the smoothest acquires the Positive, and the

the roughest the Negative Electricity. These two qualities are often to be considered both together; for, except the two bodies are of the same substance, as smooth and rough glass, white and black silk, &c. they generally differ in both, *viz.* they have not the same electric power, and at the same time their surfaces differ in smoothness. This rule, however, is not to be considered as a constant and general one; for, according to this principle, it should seem that a piece of sealing-wax, when rubbed with the hand, or paper, would acquire the Positive Electricity; but this is contrary to experience.

In case that two electric substances, equal in every respect, are rubbed together, it is to be observed that the substance which suffers the greatest friction acquires the Negative, and the other the Positive Electricity. Suppose, for instance, that a piece A of silk be drawn across another piece of silk B, in every respect equal to the former, so that the surface of the whole piece A, *i. e.* of one side of it, be successively drawn over one part of the piece B, then A will acquire the Positive, and B the Negative Electricity. The

reason of this may probably be, because the part of the piece B, over which the piece A has been drawn, has acquired a greater degree of heat; for it has been observed, that heat rather disposes bodies to be electrified Negatively.

C H A P. IV.

Of the different Methods of exciting Electrics.

RUBBING, as we observed before, is the general mean by which all electric substances that are at all excitable, may be excited. Whether they be rubbed with Electrics of a different sort, or Conductors, they always shew signs of Electricity, and in general stronger when rubbed with Conductors, and weaker when rubbed with Electrics. But besides friction, there are other means by which some Electrics may be caused to shew electric appearances: these are, by melting, or pouring a melted Electric into another substance; by heating or cooling; and by evaporating or effervescing. The particulars observed by using the first of these two methods are the following:

If

If sulphur be melted in an earthen vessel, and left to cool upon Conductors: if taken out of the vessel, when cold, it will be found strongly electrical; but not at all so, if it be left to cool upon Electrics.

If sulphur be melted in glass vessels, and afterwards left to cool, they will both acquire a strong Electricity, the sulphur Negative, and the glass Positive, whether they be left to cool upon Electrics or Conductors; however, they always acquire a stronger power in the former case than in the latter; and a stronger still, if the glass vessel is coated with metal. It is remarkable that the sulphur acquires no electricity till it begins to cool; its power increases in proportion as it contracts, and is the strongest when in the state of greatest contraction; but then the electricity of the glass vessel is at the same time the weakest.

If melted sulphur be poured into a vessel of baked wood, it acquires a Negative, and the wood a Positive Electricity; but if it be poured into sulphur, or rough glass, it acquires no sensible electricity.

Melt

Melted sulphur poured into a metal cup, and there left to cool, shews no signs of Electricity whilst in the cup; but if they are separated, they will then appear strongly electrified, the sulphur Plus, and the cup Minus. If the sulphur is again replaced in the cup, every sign of Electricity will vanish; but if, whilst they are separate, the Electricity of either, of them is taken off, they will both, on being replaced, appear possessed of that Electricity which has not been taken off.

Melted wax, poured into glass, or wood, acquires a Negative Electricity, and leaves the glass or wood Positive. But sealing-wax poured into sulphur, acquires a Positive Electricity, and leaves the sulphur Negative.

Chocolate, fresh from the mill, as it cools in the tin pans in which it is received, becomes strongly electrical; when turned out of the pans, it retains for some time this property, but soon loses it by handling. Melting it again in an iron ladle, and pouring it into the tin pans as at first, will for once, or twice, renew the power; but,
when

when the mass becomes very dry and powdery in the ladle, the Electricity is revived no more by simple melting; but if then a little olive oil be added, and mixed well with the chocolate in the ladle, on pouring it into the tin pan, as at first, it will be found to have completely recovered its electric power*.

Now that we are speaking of melted Electrics, it will not be improper to observe, that it sometimes happens, that some electric substances, by being melted and left to cool, acquire an electrical power, which they retain for a considerable time, often for months together, especially if they are preserved free from dampness and dust. Such effects have sometimes induced Electricians to think, that some bodies are possessed of a permanent or perpetual Electricity, which is as inherent in their substance as the magnetic power of a loadstone: in truth, however, no such substance has yet been found; and although rosin, sulphur,

* The above remark on chocolate, together with the method of restoring its power by means of olive oil, is a discovery of the late Mr. W. HENLY, F.R.S.

amber, silk, and some other Electrics, shew signs of Electricity for a considerable time after they have been rendered electrical, yet their power is continually diminishing till it quite vanishes. It is remarkable, however, that sulphur, resinous, bituminous substances, and silk, retain in general the electric power much longer than glass, or any other Electrics; the reason may be, that they do not attract moisture like glass and other substances, or perhaps because they are more porous.

If a stick of sealing-wax be broken into two pieces, the extremities that were contiguous will be found electrified, one positively, and the other negatively.

The property of exhibiting electrical phenomena, by means of heating and cooling, was first observed in a hard semi-pellucid fossil, known under the name of Tourmalin*. This stone, which is generally of

* This stone is called *aschentricker* by the Dutch, from its property of attracting the ashes, when laid near the fire. Linnæus calls it *lapis electricus*. See his *Flora Zeylonica*.

a deep red or purple colour, and seldom exceeds the size of a small walnut, is common in several parts of the East Indies, and especially in the island of Ceylon. Its properties in regard to Electricity are the following:

1. The Tourmalin, while kept in the same degree of heat, shews no signs of Electricity, but it will become electrical by increasing or diminishing its heat, and stronger in the latter than in the former circumstance. An exceedingly small variation of temperature is often sufficient to render the Tourmalin sensibly electrical.

2. Its Electricity does not appear all over its surface, but only on two opposite sides, which may be called its poles, and they are always in one right line with the center of the stone, and in the direction of its strata; in which direction the stone is absolutely opaque, though on the other, semitransparent.

3. Whilst the Tourmalin is heating, one of its sides (distinguished by A) is electrified

30 A COMPLETE TREATISE

fied plus, and the other side B minus. But when it is cooling, A is minus, and B is plus*.

4. If it be heated, and suffered to cool without either of its sides being touched, then A will appear positive, and B negative, all the time of its heating or cooling.

5. If this stone be excited by friction, like any other Electric, then each of its sides, or both at once, may be made Positive.

6. If the Tourmalin be heated or cooled upon some other insulated body, that body will be found electrified as well as the stone, and possessed of the Electricity contrary to that, acquired by that side of the stone which was laid upon it.

* From this law may be easily deduced, that if one side of the stone, in some circumstance or other, is growing hot, while the other is cooling, then both sides will appear possessed of the same electricity at the same time; and if only one side changes its degree of heat, while the other remains the same, then the former side only will appear electrified.

7. The

7. The Electricity of each side, or of both, may be reversed by heating or cooling the Tourmalin in contact with various substances; so if it is cooled, or heated, in contact with the palm of the hand, that side of it, which would have been positive if cooled in the open air, is now negative; and that, which would have been negative, is now positive.

8. If a Tourmalin be cut into several parts, each piece will have its positive and negative poles, corresponding to the positive and negative sides of the stone from which it was cut.

9. These properties of the Tourmalin are also observable in vacuo, but not so strong as in the open air,

10. If this stone be covered all over with some electric substance, as sealing-wax, oil, &c. it will in general show the same appearances with this coating, as without it.

11. Mr. WILLIAM CANTON hath lately observed a very vivid light to appear upon the Tourmalin, while heating in the dark: he

he can by this determine, which end of the stone will be positive, and which negative. Further, when the stone is strongly excited, it emits very strong flashes from the positive to the negative end, in the dark *.

12. In the last place, it is remarkable that the power of the Tourmalin is sometimes injured by the action of a strong fire, sometimes improved, and sometimes not at all affected by it. The laws, however, of these uncertain effects have not yet been ascertained.

The most of the above properties, which were first observed, and thought peculiar to the Tourmalin, have been found to belong to several hard precious stones; they being also made electrical by heating and cooling, and have their positive and negative sides, laying in the direction of their strata or crystals; and, in short, as far as

* The Brasilian emerald, Mr. Canton has observed to have also this property of emitting light, whilst heating in the dark: but I imagine that every other precious stone will shew it, if its electric power is sufficiently strong; since the light is a consequence of the passage of a sufficient quantity of electricity through the air, or other partly resisting medium.

has

has been observed, they have been found to act exactly like tourmalins; though some possess this property in a much higher degree than others.

The other method of producing electricity, namely, by evaporation, &c. was lately discovered by Mr. Volta; and it seems to open the way to an ample field of speculation. This ingenious philosopher discovered that the evaporation of water, and of some other fluids, and likewise that several effervescences, generated electricity. His experiments seem to shew the generality of the following law, *viz.* that fluids, or bodies in general, when reduced in the form of vapour, become electrified positively, and leave the bodies, with which they were last in contact, electrified negatively; but, on the contrary, when the vapours are condensed in the form of a fluid, then they become electrified negatively, and leave those bodies, with which they were lastly in contact, positively electrified. — Farther explanations and exemplifications of this principle will be found in the practical part of this treatise.

D

We

We shall lastly observe, in this chapter of excitation, that whenever an Electric is rubbed with another insulated substance, although it acquires an electric power, and shews electrical appearances, yet that power is very weak; and in order to obtain a considerable Electricity, it is necessary that the rubber should have a regular communication with the earth, by means of good Conductors.

CHAPTER V.

Of Communicated Electricity.

IN the preceding Chapters we have considered Electricity no further than in respect to its quality; we have remarked the differences between the Positive and the Negative, and have noted which bodies, and by what means, they could acquire this property.—But now a vast prospect is opening to our view, full of extraordinary appearances; and we are to consider in this Chapter, not the mere kind of Electricity, but its numerous effects. Under the title of

Communicated Electricity, falls almost all that is known of the subject; the passage of this virtue from one body to another is what causes its light; by being communicated to other bodies, we see its attraction; by its quick transition it is that it melts metals, destroys animal and vegetable life; and, in short, it is by this communication that the science is at all known and cultivated. In order, therefore, to preserve perspicuity and distinction, in describing such a multitude of facts, I shall employ more chapters on this subject, and arrange in each such particulars as seem most proper to be placed together; at the same time contriving to reduce the whole into as few principal heads as is possible, without confusion.

Whenever Electricity is by any means superinduced on a body, it is there confined only by Electrics, and remains with that body a longer or a shorter time, according as the Electrics that confine it are more or less perfect. A glass tube, for instance, when rubbed, acquires a quantity of that power, whatever it is, which we call

Electricity. That Electricity remains, and is perceivable upon the glass, inasmuch as it is surrounded by the air, which is an Electric; and as the air is in a more or less perfect electric state, so that virtue is retained upon the glass longer or shorter*; and because the air is never a perfect Electric, therefore the excited tube can never preserve the acquired Electricity perpetually, but is continually imparting some of it to the contiguous air, or to the conducting particles that float in that element, till at last it quite loses its power. If a finger, or any other Conductor, be presented towards an excited Electric, it will receive a spark, and in that spark part only of the Electricity of the Electric; but why not all? Because the excited Electric, being a Non-conductor, cannot convey the Electricity of all its surface to that side, to which the Conductor has been presented. Hence, if a conducting substance be successively presented to dif-

* An excited glass tube, if kept in a dry and rather warm place, for instance, at some distance from a good fire, will continue electrified above twenty hours.

ferent parts of an excited Electric, it will receive at every approach a spark, without repeating the excitation, till all the power of that Electric is exhausted, and then a new excitation is necessary in order to revive it.

Whenever a Conductor communicating with the earth is exhibited at a convenient distance to an excited Electric, it acquires on that exhibited side an Electricity contrary to that possessed by the Electric: this Electricity increases the nearer it is approached, and at last, as there is an eager attraction between Positive and Negative Electricity, the Conductor receives a spark from the Electric, and so the balance is restored. If this Conductor does not communicate with the earth, but is insulated, and approached to the excited Electric as before, then not only that side of it which is towards the Electric, but the opposite also, will appear electrified; with this difference, however, that the side, which is exposed to the influence of the Electric, has acquired an Electricity contrary to that of the excited Electric, and the opposite side

38 A COMPLETE TREATISE

an Electricity of the same kind with that of the Electric. These two different Electricities of the Conductor increase as it comes nearer to the Electric, and at last, the former receiving a spark from the latter, becomes throughout possessed of the same Electricity with the Electric from which it has received the spark. All these effects will happen in the same manner, if between the excited Electric and the approached Conductor there is interposed some other electric substance besides air; as, for instance, a thin plate of glass, rosin, sealing-wax, &c. but then a spark can never come from the excited Electric to the Conductor, except it forces, or bursts its way through the interposed Electric, as it always does through the air. This displacing of the air is what causes the noise that attends a spark, and that noise is more or less loud in proportion to the quantity of Electricity, and to the resistance it meets with in its passage.

An insulated Conductor having received the Electricity from an excited Electric (in which state it is said to be electrified by
commu-

communication) will act in every respect like the excited Electric itself, except that, when it is touched by another Conductor communicating with the earth, the former gives one spark to the latter, and by that discharges all its Electricity. The reason why an electrified Conductor loseth its Electricity all at once, when touched with another Conductor communicating with the earth, and not part of it only, like the excited Electric, is, because the Electricity belonging to the whole of the Conductor is easily conducted through its own substance, to that side, to which the other Conductor is presented *. Hence it appears that, in general, the Electricity discharged from an electrified Conductor is much more powerful, than when discharged from an Electric; for the Conductor may acquire a great quantity of Electricity from an Electric, by receiving spark after spark, and af-

* This proposition must be considered under some limitations, arising from various circumstances; for instance, if the electrified conductor is very much extended, and is touched with an imperfect conductor, or for a very short time, then it is not unlikely that some electricity will remain in it even after the spark.

terwards, if touched, will discharge it all at once, and not by little and little as it was received.

If an insulated Conductor be touched with another Conductor electrified, it will acquire part of the Electricity belonging to the electrified Conductor, and afterwards each will show signs of it. The Electricity in this case will not always be equally divided between the two Conductors, nor will it keep any proportion to the quantity of matter in each contained; but will observe the following laws.

1. If two insulated Conductors, that in respect to their external surfaces and situations are equal and similar, and both, or only one electrified, are touched together, the Electricity will be equally divided among them.

2. If their surfaces are equal and dissimilar, as, for instance, a square foot of tin foil in one piece, and another square foot of it cut in a long slip, then that body, whose
surface



surface has a greater extension, will acquire more Electricity than the other.

3. If their surfaces are unequal and dissimilar, the Electricity that each acquires after the contact, seems pretty clear from experiments, and in consequence of the above two laws, to be in a compound proportion of their surfaces, and the extensions of the same.

4. Lastly, if one of two equal and similar conductors lies with its surface contiguous to an imperfect conductor, and the other is only contiguous to the air, then the former will acquire a greater quantity of Electricity than the latter. But this property is subject to certain limitations, which, to prevent confusion, will be mentioned in the practical part.

The electric spark (*i. e.* a separate quantity of Electricity) will go a greater or less distance through the air, in order to reach a Conductor, according as its quantity is greater or less; as the parts from which it flies

flies off, and on which it strikes, are more sharp or more blunt, and as the Conductor is more or less perfect. The noise together, and the light with which the spark is attended, is greater or less, according as the Electricity is greater or less; as the parts from which it flies, and on which it strikes, are more blunt or more sharp; and as the Conductor is more or less perfect. Thus, for instance, a sharp-pointed body will throw off Electricity to, and receive it from, a greater distance, than a body of any other shape; but then that passage occasions no noise, and but little light, for, in this case, the Electricity does not come in a separate large body, but by little and little, or rather by a continued stream. If a pointed wire is concealed in a glass tube, which projects a short way beyond it, or if it is covered with tallow, bees-wax, sulphur, &c. then it will take a strong spark from an electrified Conductor.

It is remarkable, in the case of points throwing off or receiving Electricity, that a current of air is sensible at an electrified point,

point, which is always in the direction of the point, whether the Electricity is positive or negative.

The electric spark, taken upon any part of a living animal body, causeth a disagreeable sensation, which is more or less troublesome, as the spark is stronger or weaker, and the part, upon which it is taken, is more or less delicate; and also according to the particular constitution of individuals.

A pretty large quantity of Electricity pervades the substance of a Conductor of a considerable length, with a surprising and imperceptible velocity; but a small quantity of it has been found to take some little time in passing through a long, and less perfect, Conductor.

Bodies possessed of the same Electricity, whether positive or negative, repel each other. But bodies possessed of different Electricities, attract each other; and there is no electric repulsion, but between bodies possessed of the same Electricity; nor electric attraction,

44 A COMPLETE TREATISE

attraction, but between bodies possessed of different Electricities; *i. e.* between bodies positively and bodies negatively electrified *.

Electricity, strongly communicated to insulated animal bodies, quickens their pulse, and promotes their perspiration. If it is communicated to insulated fruits, fluids, and in general to every kind of bodies that are actually in a state of evaporation, it also increaseth that evaporation; and that in a greater or less degree, as those bodies are more or less subject to evaporate of themselves; as the vessels, that contain the same, are Conductors or Electrics; and as they

* This law, *i. e.* that there is no electric attraction, except between bodies possessed of different Electricities, will, perhaps, appear paradoxical, upon observing, that an excited Electric attracts small bodies, which never were by any means made electrical before; but the paradox will soon vanish, if what has been said above be considered, *i. e.* that when Conductors, and indeed Electrics too, come near an electrified body, they become actually possessed of a different Electricity. But this will appear much clearer from the experiments that are to be mentioned hereafter.

have

have a greater or less surface exposed to the open air *.

By increasing the perspiration of vegetables, Electricity promotes their growth; it having been found, after several accurate experiments, that such plants, which have been often and long electrified, have shewed a more lively and forward appearance, than others of the same kind that were not electrified †.

When Electricity is communicated to insulated vessels, containing water that is actually running from a pipe, the effects will, as far as may in gross be deduced from experiments, observe the following laws.

* Although it has been by some pretended, that Electricity caused several substances to evaporate through the pores of glass and metals, yet that could never be observed, though many accurate experiments were made for that purpose: besides, this pretended evaporation seems on all accounts exceedingly improbable.

† It is said by Mr. KOESTLIN to have been found, that negative electrization retards both animal and vegetable life.—See his Latin Dissertation on the effects of Electricity upon some organic bodies.

46 A COMPLETE TREATISE

“ 1. The electrified stream, though it
“ divides, and carries the liquid further, is
“ neither sensibly accelerated nor retarded,
“ when the pipe through which it issues is
“ not less than a line in diameter.

“ 2. Under this diameter, if the tube is
“ wide enough to let the liquid run in a
“ continued stream, Electricity accelerates
“ it a little, but less than a person would
“ imagine, if he judged by the numbers of
“ jets which are formed, and by the dis-
“ tance to which they go.

“ 3. If the tube be a capillary one, from
“ which the water only drops naturally,
“ the electrified jet not only becomes a
“ continued stream, and even divided into
“ several streams, but is also considerably
“ accelerated, and the smaller the capil-
“ lary tube is, the greater, in proportion,
“ is the acceleration.

“ 4. So great is the effect of the electric
“ virtue, that it drives the water in a con-
“ stant stream out of a very small capillary
“ tube, out of which it had not before been
“ able even to drop.”

The

The electric power has been found not to be affected by, or to affect, the magnetic virtue of a loadstone; neither is it affected by heat or cold; since an iron bar made red-hot, or any conducting substance hard frozen, when electrified, attracts, repels, gives sparks, &c. nearly in the same manner as in its natural temperature. Electric attraction is observable also in vacuo, and electric substances may also be excited in the vacuum of an air-pump; but both in a degree decreasing in proportion to the rarefaction*.

Lastly, we shall conclude this chapter with remarking, that if the face, or any part of the body, is presented to an excited Electric, or to a Conductor strongly electrified, it will feel as if a wind was blowing, or rather as if a spider's web was drawn over it; also, if the nostrils are presented to an excited Electric, they will be affected by a smell, much resembling

* This has been lately investigated by several new experiments, for which see the last part of this work.

that of phosphorus; but communicated Electricity does not occasion any such sensation, except when a large quantity of it does suddenly pass from one body to another. If bodies are kept for some time within the electric effluvia when strong, they will retain the smell that they acquire for a considerable time after.

C H A P. VI.

Of Electricity communicated to Electrics.

AS the Electric Virtue can be superinduced on Conductors by communication, so may it also be communicated to Electrics: the difference however is, as might be expected, very remarkable; for when one side of a Conductor is presented to an electrified body, the Electricity will instantly pervade its whole substance, on account of its conducting nature; whereas, when an Electric is presented to another Electric exposed, or to an electrified Conductor, it will with some difficulty acquire
any

any Electricity, because its substance is impervious to that virtue; and in order to make it acquire some, it must be several times, and in different parts, touched with the electrified body. That it is as difficult to deprive an Electric of its acquired Electricity, as it is to superinduce it on its surface, I think might easily be supposed; for the very same quality, which causeth it to acquire that power slowly (namely its being a Non-conductor) makes it also part with it slowly; and, in order absolutely to deprive the Electric of its acquired Electricity, it must be touched several times, and in almost every part of its surface, with some conducting substance.

In the preceding chapter we observed, that when an insulated Conductor is presented to an electrified body, it acquires, on the part nearest to that body, a contrary Electricity; and on the opposite part, an Electricity of the same kind with that of the electrified body; we also observed, that these two Electricities increase, as the Conductor comes near to the electrified body, and that when the Conductor is ar-

E

rived

rived within the striking distance of that body, a quantity of Electricity flies off from the latter; forces its way through the intermediate air; and, striking upon the former, renders it throughout possessed of the same Electricity. These effects are in a certain degree also observable, when an Electric, instead of a Conductor, is presented to an electrified body; for the Electric will also acquire, on different sides, contrary Electricities: these Electricities increase, as the distance decreases; but if at last a small quantity of Electricity is communicated to one part of the Electric, that Electric will not become throughout possessed of one Electricity, but will still, in some cases, shew different Electricities on different sides; and in some circumstances, many repeated changes from positive to negative Electricity may be observed upon the same Electric, as will appear from the following experiment; which, however, though mentioned by some very respectable philosophers and electricians, yet I must confess that it succeeds very seldom, if ever, clearly.

If the end of a pretty long glass tube be presented to a body electrified, for instance positively, the tube will be found electrified positively also for the space of one or two inches at the end; but, beyond that space, will be found two or three inches electrified negatively; after that, another positive Electricity will appear; and so, alternately, a positive and a negative zone will follow one another, always weaker and weaker in power, till at last they quite vanish*. Now the cause of these effects is always to be deduced from the two above-mentioned principles, *i. e.* the non-conducting quality of an Electric, and the properties of bodies in general to acquire an Electricity contrary to that possessed by another contiguous electrified body: so, in the above experiment, that end of the tube which was presented to the body electrified positively, before it received any Electricity from that body, appeared negative on the part presented to it; but, after it had received some Electricity, ap-

* See PRIESTLEY's Hist. of Elect. Per. X. Sect. v. or *Æpini Tentamen*, p. 192.

peared to be positive no further than that Electricity could be spread over its surface; but beyond that place a part of the tube appeared to be negative, on account of its contiguity to the part electrified positively; after that, another place appeared to be positive, because of its contiguity to the part electrified negatively, and so of the subsequent changes; and the positive Electricity of one part of the tube cannot mix with the adjoining negative part, so as to prevent these appearances, because the non-conducting quality of the glass will always hinder such an effect from taking place.

If to one side of an Electric sufficiently thin, as for instance a pane of common window-glass, a plate of sealing-wax, &c. be communicated one Electricity, and to the opposite side be communicated the contrary, that plate in that case is said to be *charged*, and the two Electricities can never come together, except a communication of conducting substances be made between both sides, or the Electric be broken by the power of electric attraction. When the two Electricities of a charged Electric

are by any means united, and therefore their power destroyed, that Electric is then said to be *discharged*, and the act of union of these two opposite powers is, for a reason hereafter to be mentioned, called the *electric Shock*.

In order to avoid the difficulty of communicating Electricity to an electric plate, it is customary to coat the sides of it with some conducting substance, as tin-foil, gilt paper, &c. by which means the charging and discharging becomes very easy; for when the Electricity is communicated to one part of the coating, it is immediately spread through all the parts of the Electric that are in contact with that coating; and when the Electric is to be discharged, it is sufficient to make a conducting communication between the coatings of both sides, in order to discharge entirely the Electricities of that Electric.

It will be readily understood why the coatings of both sides of an Electric should not come very near one another towards the edge of the plate, for then a communica-

tion between the same coatings is ready at hand; and although they do not absolutely touch one another, yet, when they are electrified, the Electricity will easily force a passage through the air, and, by passing over the surface of the Electric from one coating to the other, renders it incapable of receiving any charge*.

By means of charged Electrics, we may see a display of the greatest powers of Electricity; we can accumulate this power, and use it advantageously in different experiments. By considering the properties of a charged Electric, we become further and better acquainted with this science, than by any other means; and for the enumeration of these properties the following chapter is employed.

* The property of conducting the Electricity over the surface is so remarkable in some kinds of glass, that they are on this account absolutely unfit for the purpose of charging and discharging.

C H A P. VII.

Of charged Electrics, or the Leyden Phial.

IF a glass plate, whether smooth or rough, is coated with some conducting substance on both sides, so that the coatings do not come so very near the edge of the glass, as to render it unfit to be charged, and if to one of those coatings be communicated some Electricity, the other coating, while communicating with the earth, or with a sufficient quantity of conducting bodies, acquires by itself an equal quantity of the contrary Electricity; but if, whilst one side is acquiring Electricity, the opposite side does not communicate with the earth, or with a sufficient quantity of conducting substances, the glass cannot be charged*. Now the reason why, when one side of the glass is receiving one Electricity, the opposite side acquires the other, is the

* Strictly speaking, the glass in this case will be charged a little, because the air which is contiguous to its coating is not a perfect Non-conductor.

same as observed in the preceding chapter, *i. e.* the property of bodies to acquire an Electricity contrary to that possessed by a contiguous electrified body; and the cause, that hinders these two Electricities from mixing together, is the interposition of the glass plate, which is impermeable to Electricity*; but if the charge is too high, and the glass plate too thin, then the great attraction, between the two different Electricities, forces a passage through the glass, discharges it, and renders it unfit to receive another charge.

These effects happen in the same manner if the glass be not in the form of a plate,

* This remarkable property of Electricity was first satisfactorily observed (though not originally discovered, as we have already taken notice in the Introduction) at Leyden, with a bottle containing some water, which served for the inside coating, and the undesigned application of the hands on the outside served for another coating. A bottle coated on the inside and outside for the purpose of being charged, has from thence been called the *Leyden Phial*, otherwise an *electric Jar*; and the charging and discharging, in general, of coated glass, has been called the *Leyden Experiment*.

but

but in any other shape whatsoever, provided it is sufficiently thin; it being not the form, but the thickness of the glass, that makes it more or less fit to be charged: and the thinner it is, the greater charge it is capable of receiving; for the stronger in proportion is the power of the Electricity of one side, to cause a contrary Electricity on the opposite side.

How thick a glass plate or other Electric should be, to become incapable of being charged, hath not yet been ascertained.

A coated glass is capable of holding a greater charge in condensed air, than when charged under the usual pressure of the atmosphere.

If a coated glass plate, or phial, after being charged, be insulated, and only one of its sides be touched with some Conductor, that side will not part with its Electricity, because the Electricity of one side exists in consequence of the contrary Electricity on the opposite side, and both, by their mutual attraction, confine one another

another upon the surface of the glass. In order therefore to discharge that glass, both its coatings must be touched at the same time, and connected with the earth: or by means of some Conductor a communication must be made between them; and in this case the discharge is said to be made through that Conductor.

When, in order to discharge a jar, one of its coatings is touched first with a Conductor, as, for instance, with one end of a chain, nothing very particular in that case will appear*; but as soon as the other end of the chain comes within a sufficient distance of the other coating, a spark will be seen between the end of the chain, and that coating, accompanied with a noise, &c. just as when an excited Electric, or an electrified Conductor, is made to communicate with another Conductor; but the power,

* If one coating of a charged jar communicates with the earth while the other coating is exposed to the free air for some time, the charge of that jar will be silently and gradually dissipated; for while the Electricity of one side goes to the earth, the Electricity of the other is communicated to the air, which, as we observed before, is never a perfect Electric.

the

the light, and the report is in general much greater than that of a spark taken from a body simply electrified.

If the communication between the two sides of a charged jar be made by imperfect Conductors, as a slender piece of wood, a wet packthread, &c. the discharge will be made silently and without explosion.

It is remarkable, that the spark occasioned by the discharge of charged Electrics, although it is more dense, more powerful, and makes a greater report, yet is not so long as the spark drawn from an electrified Conductor.

When the discharge of a jar is made through the body of a living animal, it occasions a sudden motion, by contracting the muscles through which it passes, and gives a disagreeable sensation; for which reason, the effect of discharging an electric jar has been generally called the *electric Shock*. This shock is more sensibly felt by some persons than by others, and it is said that some people are not at all affected by it.

The

The force of the electric shock, occasioned by glasses of the same thickness, is greater or less in proportion to the quantity of coated surface, and the height of the charge. Upon this principle, the power of the said shock, by increasing the quantity of coated glass, may be augmented at pleasure, provided means be used powerful enough to charge it.

A number of coated jars connected together in such manner that their whole force may be united, and act like one jar, constitutes what is called an *electrical Battery*. This battery is the most formidable and entertaining part of an electrical apparatus, and by its use many wonderful effects are produced:—but as the performing of these belongs rather to the practical, than to the present part of this Treatise, I shall only enumerate them in this place, and reserve further particulars for the third part of this work.

In making the discharge of an electric jar, it is surprising to observe with what quickness the Electricity performs the circuit

cuit from one side of the glass to the other. It has been found to employ no perceivable time in going through a Conductor of several miles, which connected the two coatings of a phial*.

The force and noise of an electric shock is not affected by the inflexions of the Conductor, through which it goes, but it is sensibly weakened by its length; hence, when the circuit, *i. e.* the communication between the two sides of the electric phial, is made by one person touching one side with one hand, and the opposite side with the other, the shock is stronger than when the circuit is formed by many persons together joining hands.

That the Electricity finds some obstruction in going through even the best Conductors, appears evident from this, that in some cases it will prefer a short passage through the air, to a long one through Conductors, even the most perfect. This obstruction is greater in those places, where the Conductors, forming the circuit, do not

* PRIESTLEY'S Hist. of Elect. Per. VIII. Sect. ii.

lie in perfect contact; and if, the circuit being composed of Conductors of different natures, the Electricity be obliged to pass from one Conductor to another less perfect, the obstruction is still greater. If a small interruption of the circuit be made in water, on making the discharge (notwithstanding that the water is a Conductor) a spark will be seen in it, which never fails to agitate the water, and often breaks the vessel that contains it.

A strong shock, sent through an animal or a plant, puts an end to animal as well as to vegetable life. If the circuit be interrupted by one or more Electrics, or imperfect Conductors, of a moderate thickness, the electric shock will break them, and in some circumstances disperse them in every direction, and in such a manner as if the force proceeded from the center of every one of the interposed bodies *.

* In several instances the effect of a shock upon an interposed body is evidently greater on that side of it which communicates with that coating of the jar or battery, that is possessed of the positive Electricity. But of this more will be said hereafter.

A strong

A strong shock, sent through a slender piece of metal, makes it instantly red-hot, melts it, and, if the fusion is perfect, reduces it into globules of different magnitudes. If the metal be inclosed between pieces of glass, the shock, by melting it, will force it into the substance of the glass, so that afterwards it cannot be taken off without scraping part of the glass with it. In this experiment the glasses are shattered to pieces, and it is seldom that they resist the force of a strong shock.

If the glasses, inclosing the metal, be pressed by heavy weights, then a remarkable small shock is capable often not only to raise the weight, but to break such thick glasses, that otherwise require the force of a large battery. Thick pieces of glass may be also broken into innumerable fragments, by only sending a shock over a small part of their surface, which is pressed by weights, without the interposition of any metal. When these pieces of glass are not broken, they are marked by the explosion with the most lively prismatic colours, which lie sometimes confused, and some-
times

times in their prismatic order. The coloured spot is evidently formed by thin plates or scales, in part separated from the surface of the glass; and it generally occupies the space of about one inch in length, and half an inch in breadth.

In melting wires of the same metal by the electric shock, it must be observed, that the forces required for that purpose must be greater or less, according as the lengths or thicknesses of the wires are greater or less: but they are far from bearing any direct proportion to the quantity of metal; for if a wire of a given length and diameter be barely melted by a large battery, a wire of equal length, and twice the substance, would perhaps take ten such batteries to produce the same effect upon it.

When a moderate shock * is sent through an imperfect metal (especially if the circuit is formed by several pieces, as by a chain), a black dust, in the form of smoke, will be

* By a moderate shock here, I mean, one that is not able to melt the metal through which it passes.

seen to proceed from the metal, which is thought to be some of the metal itself partly calcined, and, by the violence of the explosion, forced from it.

If such circuit, or part of it, be laid upon a piece of paper, glass, or other Non-conductor, this, after the explosion, will be found stained with some indelible marks, and often shew evident signs of having been burnt. A long and permanent track may be marked upon glass, and some other bodies, by the electric explosion, if the interruption of the circuit be made upon its surface.

What is more remarkable, in considering the effects of Electricity on metals, is, that it revivifies their calces; and, like a true phlogistic process, when an explosion is made through a piece of the same, it in part returns into its metalline form. But here one might justly suspect that the phlogiston necessary to revivify the calx is forced out of other bodies that contain it, and which lie in the circuit.

F

Although

Although we observed, in the fifth chapter, that Electricity and Magnetism did not interfere with one another's action, yet that must not be understood in general, and when a large force of Electricity is meant; for this is capable not only of destroying the virtue, or of reversing the poles of a magnetic needle, but even of giving it that virtue. When the charge of ten, eight, and even a less number of square feet of coated glass is sent through a fine sewing-needle, it will often give it polarity, so that it will traverse when laid on water*. It is remarkable, that if the needle be struck, lying east and west, that end of it which is entered by the shock, will afterwards point north; but if the needle be struck, lying north and south, that end of it which lay towards the north, will in any case point north; and the needle will acquire a stronger virtue in this, than in the former case. Lastly, if the needle is set perpendicular to the horizon, and the elec-

* A smart stroke of a hammer will make a needle magnetic: but they should always be tried before the experiment; for many small needles will traverse upon water, without the electric shock, or the stroke of the hammer.

tric shock is given to either point of it, afterwards the lower extremity of the needle will point north*.

That the electric spark should kindle inflammable substances, I think might be expected, when its power has been considered in many circumstances, in which it has been observed to act as a most penetrating and extraordinary fire. In firing several substances, a small shock is sufficient; and inflammable spirits may be fired even by a spark proceeding from an electrified Conductor.

If the moderate charge of a large battery is discharged between two smooth surfaces of metals, or semi-metals, lying at a small distance from each other, a beautiful spot will be marked upon them. This consists of one central spot, and some concentric circles†, which are more or less distinct,

* See Dr. FRANKLIN's Letters, p. 90, and BECCARIA's Artificial Electricity, § 731, 732, 733, 734.

† The central spot as well as the circles lie at a little distance from one another; and they are composed of dots and cavities, indicating a true fusion.

and more or less in number, according as the metal upon which they are marked, requires a less or greater degree of heat to be melted, and as a greater or less force is employed.

If the explosion of a battery, issuing from a pointed body, as the point of a needle, be repeatedly taken upon the plain surface of a piece of metal situated at a little distance from the point, or if issuing from the surface, be taken upon the point, that metal will be marked with a coloured spot, consisting of all the prismatic colours disposed in circles, and evidently formed by scales, or thin plates of the metal separated by the force of the explosion*.

When the discharge of a battery is made by bringing the ends of two Conductors, communicating with the inside and the outside of the battery, in contact with, or at a little distance from, the surface of several conducting substances, as water, raw

* For further particulars concerning those circles, see the Phil. Transf. vol. LVIII.

meat, &c. it is observable that the Electricity, instead of entering those substances, goes over their surface, and in a lucid separate body reaches from Conductor to Conductor; sometimes it prefers a much longer passage over the surface, to a shorter one through any substance. In this case the explosion never fails to give a concussion to the body, over whose surface it passes.

The electric explosion, or even electric sparks, when taken in different kinds of air, or permanently elastic fluid, was observed by Dr. PRIESTLEY to act like a true phlogistic process*. But, upon a nicer examination, it seems that the phlogistic principle does not proceed from the electric fluid itself, but is detached, by the force of Electricity, from those Conductors, between which the explosions or sparks are taken†. It may be also mentioned in this place to have been

* See Dr. PRIESTLEY's second vol. of Observations on different Kinds of Air.

† See my Treatise on Air, and other permanently elastic Fluids, p. 433.

found by Dr. PRIESTLEY, that every kind of permanently elastic fluid is a Non-conductor of Electricity; but probably they are not all of the same degree. The colour of the electric spark, although equally visible, yet is not of the same colour in every sort of elastic fluid. In inflammable and in alkaline air, it appears of a purple or red colour; in fixed air it appears white.

The electric explosions taken upon the leaves of certain flowers, change their colour*.

Besides the above-mentioned properties of charged glass, there are a few more observed, which as yet have neither been sufficiently investigated, nor so far pursued as to be reduced under any general laws. They afford a great field for speculation, and seem to be more intimately connected with the nature of Electrics in general; but it seems not proper to make any general conclusions from the facts already known, at least so as

* Dr. PRIESTLEY's Hist. of Electricity, Per. VII.

to be inserted in this part of the present treatise. I shall therefore employ a chapter for the narration of the same, in which I shall relate the principal, and more promising experiments hitherto made, and take notice of the best conjectures offered for their explanation. This chapter will be found at the end of the third part, in which place, I think, it will be more acceptable to my readers, particularly such as have not been much conversant with Electricity, and therefore require first the description of the electrical apparatus, and the knowledge of the experiments necessary to prove the facts recited.

C H A P. VIII.

Of Atmospheric Electricity.

WHOEVER has remarked the numerous properties of Electricity already mentioned, and has considered their extensive power, will, I doubt not, be greatly surpris'd, when he compares the state, in which the science remained half a

century ago, with that in which it is at present; but his wonder will still increase, when he is told that Electricity is not only to be observed by rubbing an Electric, or warming a Tourmalin, but that it has been found to exist in the air, rain, and clouds: that thunder and lightning have been discovered to be its effects; and that, in short, whatever has the appearance of fire, or of any thing extraordinary in the atmosphere, and upon the earth, has been attributed to Electricity.

That the effects of Electricity bore a great resemblance to thunder and lightning, had been several times remarked by philosophers, and especially by the learned Abbé NOLLET; but that they should actually be found to be effects of the same cause, and that the phenomena of Electricity should be imitated by lightning, or those of lightning by Electricity, was neither thought possible, nor suspected, till the celebrated Dr. FRANKLIN made the bold assertion; and the French philosophers first, and afterwards Dr. FRANKLIN, proved the fact by undeniable arguments in the year 1752.

The



The similarity of lightning and Electricity is not to be remarked in a few appearances only, but it is observable throughout all their numerous effects, and there is not a single phenomenon of the one, but may be imitated by the other. Lightning destroys edifices, animals, trees, &c.; lightning goes through the best Conductors which it meets in its way, and, if its passage is obstructed by Electrics, or less perfect Conductors, it rends them, and disperses them in every direction; lightning burns, and melts metals and other substances; a stroke of lightning often disturbs the virtue of a magnet, and gives polarity to ferruginous substances; and all these effects, as has been observed above, may be produced by Electricity. But, independent of the great similarity existing between lightning and Electricity, what fully proves their identity is, that the matter of lightning may be actually brought down from the clouds by means of insulated and pointed metallic rods, or by electrical kites, and with it any known electrical experiment may be performed.

Clouds,

74 A COMPLETE TREATISE

Clouds, as well as rain, snow, and hail, that fall from them, are almost always electrified, but oftener negatively than positively; and the lightning, accompanied with the thunder, is the effect of the Electricity, which, darting from a cloud, or a number of clouds, highly electrified, strikes into another cloud, or else upon the earth; in which case it prefers the most lofty and pointed places, and by this stroke produces all those dreadful effects, that are known to be occasioned by lightning.

The air, at some distance from houses, trees, masts of ships, &c. is generally electrified positively, particularly in frosty, clear, or foggy weather; but how the air, the fogs, and the clouds become electrified, has not yet been clearly ascertained, although several conjectures have been offered; excepting however the principle of the electricity produced by evaporation and condensation.

After that Electricity and the matter of lightning were found to be the same thing, philosophers began to suspect the action of
Electricity

Electricity to be where it had before been less imagined, and not without reason endeavoured to reconcile to it several other natural appearances. The aurora borealis, or northern light, was soon attributed to Electricity, on observing that by this that flaming light may be imitated*, and that the aurora borealis, when very strong, has been known to disturb the magnetic needle†, which is also an effect of Electricity.

The accentions, that are often seen in the atmosphere (commonly called *falling Stars*) are thought to be electrical appearances. The same is also supposed to be the cause of such other meteors, like white clouds, that often appear by night-time, particularly in hot climates. Besides those phenomena, water-spouts, hurricanes, whirlwinds, and even earthquakes, have been at-

* The late Mr. CANTON frequently collected Electricity in a considerable degree, during the time of an aurora borealis. His apparatus for that purpose consisted of an insulated fishing rod, erected on the top of his house, and having a wire twisted round.

† See the Phil. Trans. vol. LIX. page 88.

tributed

tributed to Electricity. But now, perhaps, the reader will think philosophers too extravagant, in going so far with Electricity. Such thoughts seem at first sight to be extravagancies; but if it be considered, that they do not appear to contradict the known laws of nature, that they are not assertions absolutely void of proofs, add that they are the thoughts of great philosophers, then, I think, they may be admitted, at least so far as to be tried on proper occasions, and to be considered as the most plausible conjectures yet offered in explanation of the most surprising phenomena of nature*.

* For further conjectures, see Dr. FRANKLIN's Letters, and Dr. PRIESTLEY's Hist. of Elect.

C H A P. IX.

Advantages derived from Electricity.

NATURE, ever wise and admirable in her actions, seems to follow a certain similarity in her works with a conformity of operations, and, from the simplest to the most complicated of her objects, an analogy is observable, which, as it is wonderful to be considered, so it is instructive and useful. It is on account of this analogy, that whenever a discovery is made in any part of natural philosophy; whenever a science is advanced, we not only attain to the knowledge of that single law, or particular science, but at the same time acquire means in general of investigating the operations of nature with somewhat more certainty and accuracy; and by pursuing that analogy we are enabled to make further discoveries, and to improve every branch of knowledge. How far Electricity has contributed towards this purpose, I think is unnecessary to be further proved, when its
action

action has been shown to be so general, and so powerful, as to perform what no art can operate. But, besides the field that Electricity has opened for further discoveries, and the satisfaction of that curiosity, which before attended the contemplation of so many wonderful phenomena as have been explained by this science, there are two great advantages derived from Electricity; the one is a defence against the direful effects of lightning, and the other a remedy for many disorders incident to the human body.

In order to guard edifices or ships from being damaged by lightning, it was judiciously proposed, by Dr. FRANKLIN, to raise a metallic Conductor some feet above the highest part of the building, and continue it down the wall till it penetrated some feet into the ground; by this means the house could never receive any damage; for whenever the lightning should happen to fall upon it, it is evident that the Conductor, being of metal, and higher than any part of the building, would certainly attract it, and, by conducting it to the ground, hinder that building from receiving any damage;
for

for it is known that Electricity always strikes the nearest and best Conductors that it meets with in its way.

The reasonableness and truth of this assertion has been confirmed by numberless facts, and the practice of raising such Conductors has been found exceedingly useful, particularly in hot climates, where thunder-storms are very frequent, and the damages occasioned by the same too often experienced.

In regard to the construction of such Conductors, there have been some controversies among Electricians; and the most advantageous manner of using them has not, without a great many experiments, and but very lately, been ascertained. Some philosophers have asserted that such Conductors should terminate in a blunt end, that they might the less invite the lightning from the clouds; for a blunt end will not attract Electricity from so great distance as a sharp point. But some other philosophers have thought a pointed termination to be much preferable to a blunt one; and their assertion seems, on the following

lowing accounts, founded on much better reasoning.

A sharp-pointed Conductor, it is true, will attract Electricity from a greater distance than a blunt one, but at the same time will attract and conduct it by little and little, or rather by a continued stream, in which manner a remarkably small Conductor is capable of conducting a very great quantity of Electricity; whereas a blunt-terminated Conductor attracts the Electricity in a full separate body, or explosion, in which manner it is often made red-hot, melted, and even exploded in smoke, and by such a quantity of Electricity as perhaps would not have at all affected it, if it had been sharply pointed.

A sharp-pointed Conductor certainly invites the matter of lightning easier than a blunt one; but to invite, receive, and conduct it in small quantities, never endangers the Conductor: and the object of fixing a Conductor to a house, is to protect the house from the effects of, and not the Conductor from transmitting the lightning.

It

It is an observation much in favour of sharp-pointed Conductors, that such steeples of churches, and edifices in general, as are terminated by pointed metallic ornaments, have very seldom been known to be struck by lightning; whereas others that have flat or blunt terminations, and have a great quantity of metal in a manner insulated on their tops, are often struck by it, and it is but seldom that they escape without great damage. However it happened not long ago that a building furnished with many sharp conductors was struck by lightning*.

Besides those considerations, a sharp-pointed Conductor, by the same property of attracting Electricity more than a blunt one, may actually prevent a stroke of lightning†, to do which a blunt-ended one is absolutely incapable.

A Conductor therefore to guard a building, as it is now commonly used in con-

* See the Phil. Transf. Vol. LXXII.

† This and other properties of pointed Conductors will be made to appear very evidently by experiments.

sequence of several considerations, and experiments, should consist of one iron rod* about three quarters of an inch thick, fastened to the wall of the building, not by iron cramps, but by wooden ones. If this Conductor was quite detached from the building, and supported by wooden posts at the distance of one or two feet from the wall, it would be much better for common edifices, but it is more particularly advisable for powder-magazines, powder-mills, and all such buildings as contain combustibles ready to take fire. The upper end of the Conductor should be terminated in a pyramidal form, with the edges, as well as the point, very sharp†; and if the Conductor is of iron, it should be gilt, or painted, for the length of one or two feet. This sharp end should be elevated above the highest part of the building (as above a

* Copper would do much better than iron for a Conductor; it being a more perfect Conductor of Electricity, and at the same time not being subject to contract rust as soon as iron.

† This pyramidal termination of the Conductor is an improvement of an ingenious Electrician, Mr. SWIFT at Greenwich.

stack

stack of chimnies, to which it may be fastened) at least five or six feet. The lower end of the Conductor should be driven five or six feet into the ground, and in a direction leading from the foundations; or it would be better to connect it with the nearest piece of water, if any be at hand. If this Conductor, on account of the difficulty of adapting it to the form of the building, cannot conveniently be made of one rod, then care should be taken, that where the pieces meet, they be made to come in as perfect contact with one another as possible; for, as we observed before, Electricity finds considerable obstruction where the Conductor is interrupted.

For an edifice of a moderate size, one Conductor, in the manner already described, is perhaps sufficient; but, in order to secure a large building from sustaining any damage by lightning, there should be two, three, or more Conductors, in proportion to the extent of the building.

On board ships a chain has often been used for this purpose, which, on account of

its pliability, has been found very convenient, and easy to be managed among the rigging of the vessel; but as the Electricity finds a great obstruction in going through the several links, for which reason chains have been actually broken by the lightning, so their use has now been almost entirely laid aside; and, in their stead, copper wires a little thicker than a goose-quill have been substituted, and found to answer very well. One of these wires should be elevated two or three feet above the highest mast in the vessel; this should be continued down the mast, as far as the deck, where, by bending, it should be adapted to the surface of such parts, over which it may most conveniently be placed, and, by continuing it down the side of the vessel, it should be always made to communicate with the water of the sea.

In regard to personal security, in case a thunder-storm were to happen while a person is in a house not furnished with a proper Conductor, it is advisable not to stand near places where there is any metal, as chimnies, gilt frames, iron casements,

or

or the like; but to go into the middle of a room, and endeavour to stand or sit upon the best Non-conductor that can be found at hand, as an old chair, a stool, &c. "It is still safer (says Dr. FRANKLIN) to bring two or three mattraſſes or beds into the middle of the room, and, folding them up double, put the chair upon them; for, they not being so good Conductors as the walls, the lightning will not chooſe an interrupted course through the air of the room and the bedding, when it can go through a continued better Conductor, the wall. But where it can be had, a hammock or ſwinging bed, ſuſpended by ſilk cords, equally diſtant from the walls on every ſide, and from the cieling and floor above and below, affords the ſafeſt ſituation a perſon can have in any room whatever, and what indeed may be deemed quite free from danger of any ſtroke by lightning."

If a ſtorm was to happen whiſt a perſon is in the open fields, and far from any building, the beſt thing he can do is to retire within a ſmall diſtance of the higheſt

tree or trees he can get at; he must by no means go quite near them, but should stop at about fifteen or twenty feet from their outermost branches; for if the lightning should fall thereabout, it will very probably strike the trees; and in case a tree was to be split, he is safe enough at that distance from it.

In regard to the other great use of Electricity, viz. its application as a medicine, there have been many opinions *pro* and *contra*, and the reputation of medical Electricity has been very dubious and fluctuating; owing to the exaggerations, the mistakes, the prejudices, and the interest of those who have administered it in physical cases. But after many experiments, and after overcoming the rooted prejudice of several physicians against medical Electricity, it has been clearly observed, that, when properly managed, it is an harmless remedy, which sometimes instantaneously removes divers complaints, generally relieves and often perfectly cures various disorders, some of which could not be removed by the utmost

utmost endeavours of physicians and surgeons.

It is an important remark, that Electricity, when properly managed, if it does not effect a cure, at least it produces no bad effect; the few cases in which it seems to have produced any harm, are of a doubtful nature.

The remarks made by philosophers, relating to the effects of Electricity upon the human body in general, are the following; *viz.* that by electrization, whether positive or negative, the pulse of a person is quickened, the number of pulsations being generally increased about one sixth; and that glandular secretions, and the insensible perspiration, are promoted, and often even restored, when they had been entirely obstructed. These effects may be proved by several experiments, independent of physical cases; and I think there is nobody who will deny, that such promotions are not only beneficial, but absolutely necessary for removing several disorders. It might be naturally suspected, that the promotion

of perspiration, and of glandular secretion, were only the consequence of the accelerated pulsation, and not the immediate effect of Electricity: but the contrary is easily proved, by observing that, in various cases, the quickening of the pulsation by other means, independent of Electricity, as fear, exercise, &c. did not promote those secretions nearly so much, if at all, as electrization; and also, that glandular secretion and perspiration are often promoted by Electricity, when applied only to a particular part of the body, in which case it seldom, if ever, accelerates the pulsation.

Hitherto it has not been discovered, that the electric fluid acts within the human body by any chymical property, as most medicines generally do; but its action, by which it produces the above-mentioned effects, may be considered merely as a mechanical stimulus; for it seems to act as such, even within those parts of the body, which, especially when diseased, are mostly out of the reach of other remedies.

Formerly, in order to stimulate, or in general to apply Electricity to any diseased

part of the human body, strong shocks, or at least very pungent sparks, were thought necessary; but at present it is very reasonably established, upon experience, that the greatest electric powers which can be applied with good expectations, are exceedingly small shocks and moderate sparks, the proper force of which will be particularly described in the sequel; but that, in general, the most proper treatment is, to throw the fluid by means of a wooden point, as it is commonly called, or merely by a metallic point; in which last case, the person electrified feels only a gentle wind upon that part of the body towards which the point is directed.

By considering the above-mentioned effects of Electricity, one may naturally suspect, that in cases of preternatural discharges, the application of Electricity would be rather injurious than beneficial; because in those cases the discharge is required to be suppressed, and not promoted. In respect to this important point, it has been observed, that if strong shocks, or very pungent sparks, are given to the patients afflicted

afflicted with those discharges, the disease is seldom cured, and on the contrary is often increased; but when only the fluid is drawn from the part, by means of a wooden point, or at most exceedingly small shocks are administered, when the seat of the disease is more internal, then the discharge, &c. is at first generally promoted for a few days or hours, according to the nature of the disease and other circumstances, but afterwards it lessens by degrees, till it is quite cured. In cutaneous eruptions, the application of Electricity is generally attended with similar effects.—The eruption first spreads farther for a short time, and afterwards lessens by degrees till it quite vanishes. From these observations it appears, that the application of Electricity, when judiciously managed, does not merely promote any discharge or circulation of fluids, but rather assists the *vis vitæ*, or that innate endeavour, by which nature tends to restore the sound state of the injured parts of a living animal. It may perhaps be ever difficult to explain in what manner Electricity assists that natural endeavour; but experience shews the cer-
tainty

tainty of the fact, and with it we must be gratefully contented; for we may apply the effects to our wants, though we are ignorant of their cause, and of its mode of acting.

When an electric shock is sent through any part of the body, an instantaneous involuntary motion or convulsion is occasioned, which shews that the muscular fibres through which the shock is sent, are expanded, or in some other manner convulsed. This involuntary motion, though not so strongly, is occasioned also by sparks, and often even by drawing the fluid.—Farther, when a shock is sent through or over several substances besides the human body, a tremulous motion and an expansion is evidently occasioned, as may be shewn by many electrical experiments. Now all these observations may perhaps, in a manner, explain the action of Electricity upon the organized parts of an animal body, by comparing it with the tremulous motion given to pipes of any sort, through which fluids are transmitted, in order to accelerate their passage, and to prevent any stoppage, which might

might arise from stagnation or accumulation of gross bodies. Perhaps the reason why strong shocks are generally hurtful, may be because the irritation they give to the obstructed parts, especially when they are very minute and delicate, breaks their organization; the force being greater than those parts can naturally bear.

Independent of undeniable practical observations, when it is only admitted that Electricity promotes natural secretions and circulation, which it certainly does, there follows, that its application must be beneficial in cases of unnatural discharges; for in those cases the discharge is occasioned by the obstruction of the natural ways; but Electricity removes those obstructions, which is the same thing as to promote natural secretion and circulation; therefore, it must suppress the unnatural discharge, which can no longer exist when the natural course of the fluids has been restored.

With respect to diseases in general, two states of the affected parts should be considered.

sidered. The first is, the immediate and recent cause of the disease; and the second state is, the alteration of other parts, especially solid, which is occasioned by the long continuance of the first and principal cause; thus, for instance, the weakness or rupture of some vessels within the body, may occasion extravasation of fluids, which is the first state of the disease. Now if these extravasated fluids continue in any part of the body, they will gradually occasion a suppuration, an inflammation, or other symptoms, which vary according to innumerable circumstances. This we may consider as the second state of the disease. Again, when a palsy deprives a part of the body of its motion, the fleshy and even the more solid parts, in process of time, waste and become disfigured; which is the effect of the obstructed motion and circulation, and which we may therefore consider as the second state of the disease; and so of the rest. Now it has been observed, that the power of Electricity often removes the first state of the disorder; but the latter is very seldom cured by it. Indeed it seems almost impossible that a disfigured bone or
destroyed

destroyed organization should be restored to its sound state by means of Electricity. Dr. FRANKLIN having electrified several paralytic persons in America, observed that they were generally relieved for a few days at the beginning, but that they afterwards either did not mend, or relapsed into the state they were before the use of Electricity*. Here it must be observed, that those paralyties were mostly of a long standing, and also that the method practised by the Doctor, was to give strong shocks, which we have already remarked to be rather prejudicial.

In general, the application of Electricity has been found to be of very little use in cases of long standing; because, as we observed above, the more solid parts, by the long continuance of the disorder, have undergone such alteration, as cannot be restored by a mere stimulus, such as the electric action is supposed to be. However, sometimes diseases of many years

* See Dr. FRANKLIN's Philosophical Letters, Papers, &c. and Dr. PRIESTLEY's Hist. of Electricity.

standing

standing have been perfectly cured or relieved by means of Electricity. In these cases, therefore, although there may be less hope of effecting a cure, it is not improper to apply the power of Electricity, which, when judiciously managed, does never produce any bad effects.

Hitherto, I do not know that any authentic facts have shewn any difference between the application of different kinds of Electricity, in medical cases. Whether the patients be electrified by the prime Conductor, or the insulated rubber of the usual electrical machines, *viz.* whether they are electrified positively or negatively, seems to be quite indifferent.

In respect to the cases in which Electricity may be applied; experience shews, that in general, all kinds of obstructions, whether of motion, or circulation, or of secretion, are very often removed or alleviated by Electricity. The same may be also said of nervous disorders; both which include a great variety of diseases. To persons afflicted with the venereal disease,
or

or to pregnant women, electrization has been thought to be pernicious; but my reader may be assured, that even in those cases it may be used without fear, if it is judiciously managed. When pregnant women are to be electrified for any disorder, the shocks should be absolutely forbidden; and even when the other more gentle treatments are used, a constant attention should be given to any phenomenon that may appear in the course of the electrization; the method, of which should be increased, diminished, or suspended, according as circumstances may indicate.

Having thus given a summary view of the theory of medical Electricity, without entering into the detail of any physical cases, I shall reserve to treat at large of the practical part, for the latter end of this work.

C H A P. X.

Containing a compendious view of the principal properties of Electricity.

AFTER the laws hitherto established in the science of Electricity have been exhibited at large, and the particulars relating to each have been sufficiently considered, it will not be amiss to show in how small a compass those laws may be reduced, and how narrow is the foundation of all that has hitherto been done.

I doubt not but this recapitulation will prove very serviceable to those, who are novices in Electricity, as, by getting in memory a few particulars, they will not only reconcile all that has been said before, but will also be enabled themselves to explain most of the following experiments, and to understand the application of the hypothesis, of which we shall next proceed to treat.

H

All

All the natural bodies are divided into two classes, *i. e.* Electrics and Conductors. Electrics are such as may by some means be excited, so as to produce Electrical appearances; but Conductors are such as cannot be excited by themselves, *i. e.* without the interference of an Electric: further, electrical substances will not transmit Electricity, whereas the substance of Conductors is pervaded by it.

Electricity may be produced four ways, *i. e.* by friction, by heating and cooling, by melting, or pouring one melted substance into another, and by evaporation.

When two different bodies, except they are both Conductors, are rubbed together, they will both (provided that which is a Conductor be insulated) appear electrified, and possessed of different Electricities; so when a piece of smooth glass is rubbed with an insulated piece of leather, it acquires one kind of Electricity, called the vitreous, positive or plus Electricity; and the insulated leather acquires the other, called

called the resinous, negative or minus Electricity.

The difference between these two Electricities consists principally in the appearances of their light, and in the phenomena of attraction and repulsion.

When the positive Electricity is entering a pointed body, it causes in general the appearance of a lucid star or globule on that point; but the negative Electricity generally shows a lucid pencil of rays seeming to issue from the extremity of the pointed body.

Bodies, possessed of the same Electricity, repel each other; but bodies, possessed of different Electricities, attract each other.

Whenever bodies of any kind come within the sphere of action of an electrified body, except they are very small, and insulated, they become actually possessed of the Electricity contrary to that of the electrified body, to which they are presented.

No Electricity can be observed upon the surface of any electrified body, except that surface is contiguous to an Electric, which Electric can somehow or other acquire a contrary Electricity at a little distance. Otherwise,—no Electricity can appear upon the surface of any electrified body, except that surface is opposite to another body, which has actually acquired the contrary Electricity, and these contrarily electrified bodies are separated by an Electric*.

If

* On considering this principle, it may be asked, why any Electricity can be observed upon the surface of an electrified body, that is insulated at a considerable distance from other Conductors? Or, which is the Electric, that is contiguous to the surface of an electrified Conductor, or excited Electric, and which has actually acquired a contrary Electricity at a little distance from the said surface? To this question is answered, that the air is in general the Electric, which is opposite to the surface of any electrified body, which being not a perfect electric, does easily acquire a contrary Electricity on a stratum of its substance, that is at a little distance from the electrified body; and in consequence of this stratum, it acquires another stratum contrarily electrified, and at a little distance from the former; to this, other strata succeed, alternately possessed of positive and negative Electricities,

If the repulsion existing between bodies possessed of the same kind of Electricity be excepted, all the other electrical phenomena are occasioned by the passage of Electricity from one body to another.

A considerable quantity of Electricity exists in the atmosphere, and is certainly employed for some great purposes of nature.

The air, the clouds, the rain, the hail, the snow, and the fogs, are almost always electrified; but electrization has not been found to promote or retard coagulations, or the freezing of water.

These few laws, well considered, will be found to contain almost all that is known of the subject, and if properly applied, they

cities, and decreasing in power until they vanish, or come to the walls of the room, &c. Consider the experiment of the glass tube, mentioned in the VIth chapter, which shows that, in general, when an Electric, sufficiently dense, is presented to an electrified body, it acquires successive zones, or strata of positive and negative Electricity.

102 *A COMPLETE TREATISE*

may explain most of the experiments that follow.

Besides what has been said in this part of the present Treatise, there are several other maxims, rules, &c. to be known in Electricity; but as these mostly respect the real practice, so they will be occasionally inserted in other places, that seem better adapted to their reception.



P A R T II.

THEORY OF ELECTRICITY.

CHAP. I.

The Hypothesis of Positive and Negative Electricity.

IT is the business of Philosophy to collect the history of appearances, and from these to deduce such mechanical laws, as may either be themselves of immediate use, or lead to the discovery of other facts more interesting and necessary for the happiness of human kind. After a number of such constant appearances, which are called natural laws, have been established, and confirmed by a sufficient number of experiments, it is then proper to investigate the cause of those effects; which, if it is once discovered, and its mode of acting is ascertained, puts an end to the trouble of experimental investigation, and renders the application of its effects certain, and determinate.

Causes and effects are so intimately connected and dependent on each other, that throughout the system of nature we every where discover a series of energies, which whilst they are depending on, and derived from, their preceding terms, are at the same time the causes of their succeeding ones. But what is the first cause of all the rest, which being not the effect of any preceding, may be called the source of all, and the first term in the series? In contemplating this source, the mind is lost in wonder, and, after we are advanced a few steps, we find that a cloud obstructs our further progress, and, from continuing our inquiry and contemplation, nothing more can be derived but an argument to prove the imbecillity and shortness of our understanding. This however is not the subject of the present Treatise; and all I meant to deduce is, that, after the laws of Electricity have been considered, it is necessary that we should go a little further, and investigate, if possible, the immediate cause of that property in nature, or consider the most probable conjectures that have been offered on this subject: by the knowledge of which we may explain all
the

the known electrical appearances, and adapt their effects to our purposes with somewhat more certainty and precision.

The vast number of hypotheses that have been framed in explaining the electrical phenomena, from the infancy of the science to the present time, may be easily imagined, by considering the great number of labourers, and the discoveries that have been produced without intermission in this field of wonders. It would be not only an endless work to relate all the hypotheses hitherto offered, but also an useless one, when they have been evidently contradicted by several experiments, and after they have all given place to the hypothesis of a single electric fluid, which generally goes under the name of Dr. FRANKLIN'S. That although this hypothesis explains all the known electrical appearances, it is however not a demonstrable truth, but the most probable supposition, I confess; and, in order that a due distinction might be preserved between the knowledge of facts, and the supposition of their immediate cause, I have separated the former from the latter, and followed that method

method which seemed more philosophical and instructive; but now to make further apologies for admitting this hypothesis, at a time when numberless experiments speak clear in its favour, would be doing an injury to the philosophical world in general, and especially to the ingenious philosophers that proposed and improved it. I shall therefore, without further preamble, lay it down as it is now commonly and reasonably admitted; and shall use it in the explanation of the following experiments.

All the phenomena called Electrical are supposed to be effected by an invisible subtle fluid existing in all the bodies of the earth. It is supposed also that this fluid is very elastic, *i. e.* repulsive of its own particles, but attractive of the particles of other matter.

When a body does not show any electrical appearances, it is then supposed to contain its natural quantity of electric fluid (but whether that quantity bears any proportion to the quantity of matter in general, or not, is uncertain), and therefore that body is

said to be in its *natural*, or *non-electrified state*: but if a body shows any electrical appearances, it is then said to be electrified, and it is supposed that it has either acquired an additional quantity of electric fluid, or that it has lost some of its natural share. A body having received an additional quantity of electric fluid, is said to be *overcharged*, or *positively electrified*; and a body that has lost part of its natural quantity of electric fluid, is said to be *undercharged*, or *negatively electrified*.

From hence it appears, why the terms *positive* and *negative*, or *plus* and *minus* Electricity came to be used; for the first signifies a real plus, or superfluity, and the second a real minus, or deficiency of the quantity of electric fluid proper to a body.

By this hypothesis, which is analogous to the other phenomena of nature, the electrical appearances are easily explained, and there is not a single experiment that seems to contradict it. First it appears, that when an electric and a conducting substance are rubbed together, the Electricity is not then produced; but by the action of rubbing, one
body

body pumps, as it were, the electric fluid from the other *: hence, if one becomes overcharged with it, or positively electrified,

* By what mechanism one body extracts the electric fluid from the other is not yet known. The celebrated Father BECCARIA supposes that the action of rubbing increaseth the capacity of the Electric, *i. e.* renders that part of the Electric, which is actually under the rubber, capable of containing a greater quantity of electric fluid; hence it receives from the rubber an additional share of fluid: which is manifested upon the surface of the Electric, when that surface is come out of the rubber; in which state it loses, or, as it were, contracts its capacity. Father BECCARIA's experiment to prove this supposition is the following:—He caused a glass plate to be rubbed by a rubber applied on one side of the plate, while it was turning vertically; and holding at the same time a linen thread on the other side of the plate, just opposite to the rubber, he observed, that the thread was not attracted by that part of the glass which corresponded to the rubber, but by that which was opposite to the surface of the glass that had just come out of the rubber; which shows that the fluid, acquired by the glass plate, did not manifest its power until the surface of the glass was come out of the rubber. But, query, in what manner does the glass augment its capacity of holding the electric fluid by the action of the rubber? See Dr. FRANKLIN's Letters, &c. § 34. Besides this, there are other experiments to be mentioned in the course of this work, which clearly shew that the capacity of a body to hold Electricity is increased by the vicinity of certain other bodies.

the other must necessarily be undercharged, or electrified negatively, except its deficiency be supplied by other bodies communicating with it. From hence also appears the reason, why, when an Electric is rubbed with an insulated rubber, it can acquire but little Electricity; because in that case, the rubber, not communicating with other Conductors, can supply the Electric with only that small quantity of fluid which belongs to itself, or which it collects from the contiguous air.

Electric attraction is easily explained; for this does not exist, except between bodies differently electrified; which must certainly attract each other, on account of the attraction existing between the superfluous electric fluid of the bodies electrified positively, and the undercharged matter of the bodies electrified negatively.

As to the repulsion existing between bodies possessed of the same Electricity; in order to understand its explanation thoroughly, the reader must be reminded of the principle mentioned in the preceding part, which is, that no Electricity, *i. e.* the electric

tric fluid proper to a body, can neither be augmented nor diminished upon the surface of that body, except the said surface is contiguous to an Electric, which can acquire a contrary Electricity at a little distance; from whence it follows, that no Electricity can be displayed upon the facing surfaces of two bodies that are sufficiently near one another, and both possessed of the same Electricity; for the air that stands between those contiguous surfaces has no liberty of acquiring any contrary Electricity. This being premised, the explanation of Electric repulsion becomes very easy. Suppose, for instance, that two small bodies are freely suspended by insulated threads, so that when they are not electrified they may hang contiguous to one another. Now suppose those bodies to be electrified either positively or negatively, and then they must repel one another; for either the increased, or the diminished natural quantity of electric fluid in those bodies, will endeavour to diffuse itself equally over every part of the surfaces of those bodies; and this endeavour will cause the said bodies to recede from each other, so that a quantity of air may be interposed between their surfaces, sufficient

to acquire a contrary Electricity at a little distance from the said surfaces.—Otherwise, if the bodies, possessed of the same Electricity, do not repel each other, so that a sufficient quantity of air may be interposed between their surfaces, the increased quantity of electric fluid, when the bodies are electrified positively, or the remnant of it, when the bodies are electrified negatively, by the above principle, cannot be diffused equally throughout, or over the surfaces of those bodies; for no Electricity can appear upon the surfaces of bodies in contact, or that are very near one another. But the electric fluid, by attracting the particles of matter, endeavours to diffuse itself equally throughout, or over the surfaces of those bodies; therefore the said bodies are, by this endeavour, forced to repel one another.

I think it is unnecessary to insist further upon the above explanation; for the principle, upon which it depends, seems universal and clear, so that it may be easily applied to explain electric repulsion in general, as well as the repulsion between the above-mentioned two bodies.

The

The charging of coated glass, and other Electrics, as well as the other phenomena of Electricity, may also be easily accounted for by the above-mentioned hypothesis of Electricity; but I think it unnecessary to enumerate and account for all the particulars in this place, as we shall have occasion to speak of them in the explanation of the experiments in the third part.

C H A P. II.

Of the Nature of the electric Fluid.

THE human mind, never satisfied, after the cause of some effects has been discovered, or only guessed at, attempts to investigate some more intimate quality, and even the origin of that supposed cause, making further suppositions, and framing other hypotheses, which, by the course of things, must certainly be less probable than the former. This unlimited endeavour to acquire knowledge is often too ridiculous to be pursued, on account of its abstruseness and uncertainty, especially when the steps immediately preceding the subject in hand have but a small degree of probability. It is from hence that Philosophers have frequently

When nothing more than electric attraction and repulsion had been observed, Electricians supposed that these were effected by a kind of unctuous effluvia proceeding immediately from the electrified body; but

when

when the light, the burning quality, the phosphoreal smell, &c. was perceived to be produced by excited Electrics, then it was naturally supposed, that the electric fluid was of the same nature with fire. This opinion has prevailed much among several Philosophers, and it is from hence, that the electric fluid has been commonly called Electric Fire. Besides this supposed identity of the electric fluid, and the element of fire, there have been two other opinions concerning the essence of this fluid; it having been thought by some to be the *ether* of Sir ISAAC NEWTON, and by others (whose opinion seems to be the most probable) to be a fluid *sui generis*, *i. e.* different from all other known fluids.

In order the more regularly to examine these conjectures, it will be necessary to premise something in regard to the nature of fire, at least so much as is sufficient for the present purpose.

The element of fire may be considered in regard to its spring, to the different states of its existence, and to its effects. In regard to
its

its origin it is commonly specified under the names of Celestial, Subterraneous, and Culinary Fire; understanding by the first, that which proceeds from the sun, and, by being dispersed throughout the universe, gives life and motion to almost every thing that exists; by the second, that which is the cause of volcanos, hot springs, &c. and lastly, under the name of Culinary Fire, understanding that which is commonly produced upon the earth, by burning several substances. These distinctions however are little if at all useful; for, whatever be the origin of fire, its effects are always the same.

In respect to the different states of its existence, the Chymists know only two; the first obvious one, and indeed that, to which only is given the name of Fire, is that actual agitation of the particles of that element, which produces the complex idea of lucid, hot, &c. that is commonly understood under the name *Fire*; and the other state is the real principle of fire existing as a constituent principle in several, and perhaps all substances; or, that matter, whose particles, when agitated in a peculiar and

violent manner, produce the common sensible fire.

This, which we may call fire in an inactive state, is the *Phlogiston* of the Chymists, and is that, which when united in a sufficient quantity with other substances, renders them inflammable. That this principle does really exist, is beyond a doubt; we may transfer it from one body to another; we may render a body inflammable, which in its own nature is not so, by superinducing on it the phlogiston; and we may reduce a body naturally inflammable, to a substance not inflammable, by depriving it of its phlogiston.

Now the electric fluid, as far as we can determine, bears but a very small resemblance to the above-mentioned two states of fire; for although it exists in different bodies, as the phlogiston, yet when we compare its other attributes with those of fire, we then immediately perceive it to be not the same, but a different principle. In the first place, if they were both the same thing, they should be always together, and where-
ever

ever such a quantity of fire exists, there the same quantity of electric fluid should be found: but this is contrary to experiments; for a piece of metal or other substance may acquire a great degree of heat without appearing at all electrified; and on the other hand, may be strongly electrified without acquiring by it any sensible degree of heat, or any addition to its phlogiston. Secondly, fire penetrates every known substance, and an exceedingly small quantity of it is diffused alike throughout bodies of every kind; whereas the electric fluid pervades only Conductors*. Thirdly, the electric fluid goes through a very long Conductor in a space of time almost instantaneous; but fire is very slowly propagated. I might enumerate several other improprieties attending this hypothesis of the sameness of fire and the electric fluid, but those already mentioned are, I think, sufficient to induce my readers to suppose otherwise.

* Here may be observed, that heat pervades more easily the substance of some good Conductors of Electricity; but the rule however is not general.

Dr. PRIESTLEY, on observing that the electric explosion, taken in different kinds of air, acts, in general, like other phlogistic processes, supposes that the electric matter either is, or contains, phlogiston †. In regard to this, I would observe, that there is no necessity of supposing the electric matter either to be, or contain phlogiston, on that account; for the phlogiston, in this case, may, by the force of the electric explosion, be extricated, either from the surface of the Conductors, between which the explosion is taken, or from particles of heterogeneous matter floating in that air, in which the explosion is made §.

In regard to the similarity between the effects of fire, and the effects of the electric fluid, it will be very obvious to remark, that although fire is, in several instances produced by the electric fluid, yet we should never confound the one with the other, and

† Observations on different Kinds of Air, vol. II. sec. XIII.

§ See my Treatise on Air, &c. p. 433.

consider them both as the same thing; for it is well known that friction produces fire, and it is by no means surprising that the electric fluid, by the rapidity of its motion, through substances, that in some manner obstruct its passage, should generate light, heat, rarefaction, and the other effects of fire *.

Mr. HENLY, in consequence of several very interesting experiments, made by himself, supposed, that, although the electric fluid may be neither phlogiston nor fire, yet that it is a modification of that element, which, while in a quiescent state, is called Phlogiston, and when violently agitated is called Fire. We constantly observe (says he) I. That if two bodies are rubbed together, which have an equal quantity of phlogiston (which is the case with bodies of the same kind, as glass and glass, metal and metal, &c.) they acquire either very little, or no Electricity at all. II. That as one of

* Here it is proper to observe, that the electric fluid shows no effects of fire, except when it goes through some medium that obstructs its free passage.

the bodies has a greater quantity of phlogiston than the other, so they acquire a greater quantity of Electricity, as when glass is rubbed with metal. III. That a certain degree of friction produces Electricity, and that a more violent friction produces fire, but no Electricity, as may be observed by rubbing together two pieces of baked wood, of glass, &c. IV. And that in general, bodies, possessed of a greater quantity of phlogiston, give the electric fluid to bodies that have less of it, *i. e.* they acquire the negative Electricity, when rubbed with bodies that have a less quantity of phlogiston*.

* Mr. HENLY, in order to try what Electricity different substances would acquire, insulated them upon sticks of sealing wax, and rubbed them against his woollen coat, or waistcoat. In this manner he tried a vast number of vegetable, animal, mineral, and artificial substances; and he discovered a very remarkable law, which is, that such substances, which have a great quantity of phlogiston, as vegetable substances, and particularly the hot, aromatic plants and seeds, &c. *give* the electric fluid; that is, they acquire the negative Electricity when rubbed against woollen cloths; and, that such substances, which have but little phlogiston (as most animal substances) *acquire* the electric fluid from the said cloths, *i. e.* they are electrified positively. See the Phil. Transf. for the year 1777.

From

From these observations we gather, that the electric fluid, and fire, are produced by similar operations, and are both extracted from bodies abounding with phlogiston: and hence he concludes, that the phlogiston, the electric fluid, and fire, are only different modifications of the very same element; the first being its quiescent state of existence, the second its first active, and the last its more violent state of agitation: like fermentation producing first wine, secondly vinegar, lastly putrefaction.

As to the identity of the Electric, and the ethereal fluid, it seems to me quite an improbable, or rather a futile and insignificant hypothesis; for this ether is not a real, existing, but merely an *hypothetical fluid*, supposed by different Philosophers to be endued with different properties, and to be an element of several principles. Some suppose it to be the element of fire itself, others make it the cause of attraction, others again derive animal spirits from it, &c.; but the truth is, that not only the essence, or properties, of this fluid, but even the reality of its existence is absolutely unknown.

According

According to Sir ISAAC NEWTON's supposition, this ether is an exceedingly subtle and elastic fluid, dispersed throughout all the universe, and whose particles repel the particles of other matter. But on this supposition the electric fluid is different from ether; for, although the former is subtle, and elastic, like the latter, yet (as Dr. PRIESTLEY observes) it is not repulsive like the ether, but attractive of all other matter.

C H A P. III.

Of the Nature of Electrics and Conductors.

THE remarkable difference existing between the two classes of bodies in regard to Electricity, *i. e.* Electrics and Conductors, naturally induces an Electrician to inquire what is that principle in bodies, or by what mechanism some substances become capable of transmitting the electric fluid, whilst others are impervious to it?

In regard to the explanation of these two remarkable properties, there have been, as might be expected, several conjectures offered; but, except one probable hypothesis, there is nothing as yet ascertained. When the catalogue of Electrics and Conductors was very short and imperfect, it was supposed that, the only two conducting principles were metals, and water; and that all substances were nearer, or further from the nature of a perfect Conductor, in proportion as they contained a greater or less quantity

tity of the above principles in their composition. Wood, for instance, was supposed to be a Conductor only on account of the water it contained within its pores; accordingly, it was observed, that the greater quantity of moisture the wood contained, the better Conductor it proved to be, and on the contrary, that it acted more like an Electric, in proportion as it was freed from its moisture. But when water itself was observed to be a bad Conductor, and hot air, and charcoal to be good Conductors, especially the latter, which substances, it is well known, contain no water nor metal, at least not in such a quantity as is sufficient to change a non-conducting substance into a Conductor, then the former supposition was laid aside, and another was offered by Dr. PRIESTLEY, in his second volume of Observations on the different Kinds of Air *, which seems to be well founded.

The Doctor, considering what the principle is, which Conductors possess in com-

* Sec. XIV.

mon,

mon, and finding one of their common ingredients to be the phlogiston, deduces from thence, that the conducting quality is absolutely owing to the phlogiston.

“ Had there been (says he) any phlogiston in water, I should have concluded, that there had been no conducting power in nature; but in consequence of some union of this principle with some base. In this, metals and charcoal exactly agree:—while they have the phlogiston, they conduct; when deprived of it, they will not conduct.”

And in a note to this paragraph, he subjoins:

“ Having since found, that long agitation in the purest water injures air, so that a candle will not burn in it afterwards, which is precisely the effect of all phlogistic processes, I now conclude that the maxim, suggested in this paragraph, is universally true.”

This hypothesis seems very ingenious and probable; and, till any other more
8
plausible

plausible be offered, or experiments contradict it, I think we may safely make use of it in pursuing our electrical investigations, and endeavour to reconcile to it the phenomena already discovered in Electricity.

C H A P. IV.

Of the Place occupied by the electric Fluid.

BEFORE we quit the hypothetical part of this Treatise, it may be proper to say something concerning the residence of the electric fluid, either natural to a body, or superinduced on it. That the electric fluid, proper to a body when in its natural state, is equally diffused throughout all its substance, I think no one will deny; because that fluid is attractive of the particles of all other matter, and the particles of other matter are attractive of the electric fluid; and as this attraction is in proportion to the quantity of homogeneous matter, any quantity of matter will certainly attract a quantity of electric fluid proportionable to itself; therefore, the

electric fluid must be equally diffused throughout all the parts of that portion of matter. This proposition, however, will take place only in speaking of Conductors; for it is founded upon the supposition, that the electric fluid, proper to a body in its natural state, does freely pervade that substance; but whether this is a fact respecting Electrics, or not, hath not hitherto been ascertained. As far as may be judged from experiments, I should suppose this rule to hold good with Electrics also; and my supposition is founded upon the following reasoning:—All the Electrics, when made very hot, become Conductors*; in that state, therefore, the above rule must hold good, *i. e.* the electric fluid, proper to their quantity of matter, must be equally diffused throughout their substance: and as all the Electrics in nature, before they became such (we may suppose) were Conductors; in that state they certainly had

* As this proposition has been found true in all the experiments hitherto made, I think it may be considered very properly, as a general law in the science of Electricity.

their

their proper share of fluid. Now as they afterwards cool, and become Electrics, it should seem that the change of their nature could not affect the equal diffusion of the electric fluid, which took place whilst they were in a conducting state *. In consequence of this consideration, the difference between a Conductor and a Non-conductor, in regard to their natural quantity of electric fluid, is, that in the former, the fluid may easily move, whereas in the latter, it is confined in its pores. But it may be asked, whether a quantity of electric matter contains as much electric fluid as an equal quantity of conducting matter; a piece of rosin, for instance, when melted, does it contain more, less, or the same quantity, of electric fluid as when cold? To this question I can give no satisfactory answer; for, by the experiments hitherto made, nothing certain has been deter-

* The only consideration which seems to oppose some difficulty to this hypothesis is the property which several electric substances have, of becoming electrical by cooling or coagulating. See the 4th chap. of the preceding part.

mined. Dr. PRIESTLEY, in order to ascertain this matter, made the following experiment:—He made a piece of glass red-hot (in which state it is a Conductor) and placing it upon an insulated piece of copper, left it in that situation till quite cold (*i. e.* till it became an Electric); but in all the time of its cooling, no Electricity of any kind was perceived, either in the copper or glass; which would have certainly been the case, if the piece of glass had contained either more or less fluid when in an Electric, than when in a conducting state*. This experiment seems to give a decisive answer to the above question; but when the experiments, mentioned in the first part, of melting an electric substance into another, and other facts of a similar nature, are duly considered, they seem to make the answer again difficult †. It must therefore be confessed,

* History of Electricity, p. 716.—Experiments of a similar nature are met with in BECCARIA's *Elettricismo Artificiale*.

† The wax-chandlers, in forming their mass into sticks, &c. find it so strongly attractive of dust, &c.

fed, that this matter remains as yet unsettled; and nothing but further experiments, and the discovery of other facts, can determine any thing satisfactory about it.

In respect to the place occupied by the electric fluid superinduced on a body, it has been thought, by several ingenious persons, that, when a body is electrified, all the superfluous fluid, or all the deficiency of it, in case the body is electrified negatively, resides as a kind of atmosphere all around the body; to this atmosphere they attribute the phosphoreal smell, and that tickling sensation produced by an excited Electric; and they even suppose that these atmospheres may be made visible. But to this assertion it is answered by others, that if the Electricity communicated to a body did reside round it like an atmosphere, it should certainly repel the air contiguous to that body; but this is not the result of ex-

periments; that they are obliged to use great caution in keeping it at a sufficient distance from the charcoal fire, over which they work, lest it should (as sometimes happens) cover itself with ashes, and thus spoil the work.

periments;

periments; for it has been found that the electric atmosphere, however dense, if it does at all exist, has no effect upon the air contiguous to the electrified body, nor has the motion of the air, even a violent wind, any effect upon the atmosphere. In regard to the above-mentioned sensations of phos- phoreal smell, &c. it is thought that they are only occasioned by the electric fluid entering or going out of the skin in a very subdivided manner.

From what may be deduced from experiments, it appears that, although the electric fluid is transmitted through the substance of Conductors, yet no communicated Electricity can be observed within a sufficiently narrow cavity of an electrified body; besides, if two bodies of the same size and figure, but of different densities, are electrified together, and afterwards separated, they will acquire each the same quantity of Electricity; *i. e.* the Electricity that they acquire will be proportional to their surfaces, and not to their respective quantities of matter.

We may lastly conclude, that the Electricity communicated to a body, lies not diffused throughout the substance of that body, but on that surface of it which is contiguous to a free Electric, *i. e.* to an Electric, that is not surrounded by an homologous Electricity.

P A R T II.



PRACTICAL ELECTRICITY.

CHAP. I.

Of the electrical Apparatus in general.

HITHERTO we have treated of Electricity only theoretically, having noted what has been found uniformly certain relative to this subject, and having exhibited a view of the most probable conjectures offered in explanation of electrical appearances ; but Electricity being a science, that requires a more practical management, than perhaps any other branch of natural philosophy, it is necessary that we should now treat of it practically, and give the best directions we are able, both in regard to the construction of the necessary apparatus, and to the performance of the experiments, not only requisite in proving

the foregoing Propositions, but such also as are pleasing and entertaining.

In this part of my work the reader will perhaps find more novelty than he expects; for, considering the number of books that have been lately published on this subject, one would imagine that all the experiments possible to be exhibited with an electrical machine, and its appendages, have already been described. The case however is much the contrary; for not only the old experiments have been diversified, but a variety of new ones have been invented, and even the principal part of the apparatus has undergone several changes and improvements,

In order the more regularly to proceed in the description of the electrical apparatus, it will not be improper to divide its parts into three classes; considering in the first, the instruments necessary to produce Electricity; in the second, those proper to accumulate, retain, and employ it; and lastly, those necessary to measure its quantity, and ascertain its quality.

The

The principal instrument to produce Electricity, is the electrical Machine, *i. e.* a machine capable by any means of exciting an Electric, so as to produce electrical appearances. The construction of those machines, from their first invention to the present time, has undergone so many changes, and their forms have been so much varied, that it would be very difficult, and even tedious, to describe those only which are most frequently in use. Every maker, and almost every Electrician, constructs his own machines in a manner different from the rest; and, as new facts or long practice points out some imperfections, the Electrician is ready to contrive a new method to correct the preceding errors. Indeed the rapid advance of the science is mostly owing to this change, and variety of constructions; for whether casual, or designed, a new construction has generally either produced some discovery of importance, or exposed some defect in the apparatus, and management of the same.

That the reader may be left at the

liberty of choosing the form of his machine, I shall in this chapter lay down the most necessary rules to construct electrical machines in general; and shall reserve for the next chapter the particular description of some machines, that are the most useful, and which contain all the improvements hitherto made.

The principal parts of the machine are the Electric, the moving Engine, the Rubber, and the prime Conductor, *i. e.* an insulated Conductor, which immediately receives the Electricity from the excited Electric.

The Electric was formerly used of different substances, as glass, rosin, sulphur, sealing-wax, &c.; and of different forms, as cylinders, globes, spheroids, &c. This diversity then obtained on two accounts; first, because it was not ascertained, which substance or form would answer best; and secondly, on account of producing a negative or positive Electricity, at the pleasure of the operator; for before the Electricity
of

of the insulated rubber was discovered, sulphur, rough glass, or sealing-wax, was generally used for the negative Electricity. At present, smooth glass only is used; for when the machine has an insulated rubber, the operator may produce positive or negative Electricity at his pleasure, without changing the Electric. In regard to the form of the glass, those commonly used at present are globes, and cylinders. The most convenient size for a globe, is from nine to twelve inches diameter: they are made with one neck, which is cemented * to a strong brass cap, in order to adapt them to a proper frame. The cylinders are made with two necks; they are used to the greatest advantage without any axis, and their common size is from four inches diameter and eight inches long, to twelve inches diameter and two feet

* The best cement for electrical purposes is made with two parts of rosin, two of bees-wax, and one of the powder of red okre. These ingredients are melted, and mixed together in any vessel over the fire; and afterwards kept for use. This kind of cement sticks very fast, and is much preferable to rosin alone, as it is not so brittle, and at the same time insulates equally well.

long;

long; though some have been made in London even of twenty-four inches in diameter. The glass generally used is the best flint, though it is not yet absolutely determined, which kind of metal is the best for electrical globes, or cylinders. The thickness of the glass seems immaterial, but perhaps the thinnest is preferable. It has often happened, that glass globes, and cylinders, in the act of whirling, have burst in innumerable pieces, with great violence, and with some danger to the by-standers. Those accidents are supposed to happen when the globes, or cylinders, after being blown, are suddenly cooled. It will therefore be necessary to enjoin the workman to let them pass gradually, from the heat of the glass-house, to the atmospherical temperature.

It has been long questioned whether a coating of some electric substance, as rosin, turpentine, &c. on the inside surface of the glass, has any effect to increase its electrical power; but now it seems pretty well determined, that if it does not increase the power of a good glass globe or cylinder, at

least it does considerably improve a bad one. I have several times put a coating of rosin on the inside surface of phials and tubes, and have constantly found, that the worst of them received some improvement by it.

The most approved composition for lining glass globes, or cylinders, is made with four parts of Venice turpentine, one part of rosin, and one part of bees-wax. This composition must be boiled for about two hours over a gentle fire, and must be kept stirring very often: afterwards it is left to cool, and reserved for use. When a globe or cylinder is to be lined with this mixture, a sufficient quantity of it is to be broken into small pieces, and introduced into the glass; then, by holding the glass near the fire, the mixture is melted, and equally spread over all its internal surface, to about the thickness of a sixpence. In this operation care must be taken, that the glass be made hot gradually, and be continually turned, so as to be heated equally in all parts, otherwise it is apt to break in the operation.

In

In respect to the Engine which is to give motion to the Electric, multiplying wheels have been generally used ; which, properly adapted, might give the Electric a quick motion, while they are conveniently turned by a winch. The usual method is, to fix a wheel on one side of the frame of the machine, which is turned by a winch, and has a groove round its circumference. Upon the brass cap of the neck of the glass globe, or one of the necks of the cylinder, a pulley is fixed, the diameter of which is about the third or fourth part of the diameter of the wheel ; then a string or strap is put over the wheel and the pulley, and by these means, when the winch is turned, the globe or cylinder makes three or four revolutions, for one revolution of the wheel. There is an inconvenience generally attending this construction, which is, that the string is sometimes so very slack, that the machine cannot work. To remedy this inconvenience, the wheel should be made moveable with respect to the Electric, so that by means of a screw it might be fixed at the proper distance ; or else the pulley

pulley should have several grooves of different radiuses on its circumference.

It has been customary with some, to turn the cylinder simply with a winch, without any accelerated motion; but that has not been thought sufficient to produce the greatest electric power, the glass is capable of giving; for the globe or cylinder should properly make about six revolutions in a second, which is more than can be conveniently done with the winch only. This method, however, has been lately adopted by Mr. NAIRNE, who by a nice construction of every part has produced a very powerful electrical machine; of which I shall give a description in the sequel.

Instead of the pulley and the string, as above described, a wheel and pinion, or a wheel, and an endless screw, has been also used. This construction answers perhaps as well as any other; but it must be constructed with great nicety, otherwise, it is apt to make a disagreeable rattling, and without frequent oiling, soon wears away by the great friction of its parts.

The

The next thing belonging to the Electrical machine, necessary to be described, is the rubber, which is to excite the Electric. The rubber, as it is now made, is nothing more than a silk cushion stuffed with hair; and over this cushion is put a piece of leather, on which some amalgam * has been rubbed, so as to stick as fast as possible to the leather. Some time ago it was generally used, and it is now customary also, to make the rubber of red basil skin stuffed with hair; but the silk one, as above described (which is an improvement of Dr. NOOTH) is much preferable. If this silk cushion, on account of adapting it to the surface of the glass, is to be fixed upon a metal plate, then care should be taken to make the plate free from sharp points, edges, or corners,

* The amalgam has been found to excite smooth glass most powerfully. Any metal, dissolved in quick-silver, will perhaps do equally well, but the amalgam that has been generally used, is made with two parts of quick-silver and one of tin-foil, with a small quantity of powdered chalk, mixed together until it becomes a mass, like paste. An amalgam made with one part of zinc, and four or five-parts of mercury, answers still better, as discovered by Dr. HIGGINS. Mosaic gold may also be used.

and

and it should be as much as possible concealed, or covered with silk. In short, to construct the rubber properly, it must be made in such a manner, that the side of it, which the surface of the glass enters in whirling, may be as perfect a Conductor as it can be made, in order to supply Electricity as quick as possible; and the opposite part should be as much a Non-conductor as possible, in order that none of the fluid accumulated upon the glass, may return back to the rubber; which has been found by experiment to be the case, when the rubber is not made in a proper manner. For which reason a piece of silk is also added to the extremity of the leather.—Mr. NAIRNE's rubber consists of silk only put over the leather cushion, and very little amalgam is used with it.

The rubber should be supported by a spring, by which means it may easily suit any inequalities that may be found on the surface of the glass; and by a screw it may be made to press harder or softer, as occasion may require. It should also be insulated in whatever manner is most convenient;

nient; for whenever insulation is not required, a chain or wire, &c. may be occasionally hung upon it, and thus it may be made to communicate with the earth, or with any other body, at pleasure; whereas, when there is not a contrivance for insulating the rubber, many of the most curious experiments in Electricity cannot be performed with the machine.

We come now to consider the prime Conductor, or first Conductor, which is nothing more than an insulated conducting substance furnished with one or more points at one end, in order to collect the Electricity immediately from the Electric. When the Conductor is of a moderate size, it is usual to make it of hollow brass; but when it is very large, then, on account of the price of the materials, it is made of paste-board, covered with tin-foil, or gilt paper. The Conductor is generally made cylindrical; but let the form be what it will, it should always be made perfectly free from points, or sharp edges; and if holes are to be made in it, which on many accounts are very convenient, they should be well rounded,
ed,

ed, and made perfectly smooth. Further, that end of the prime Conductor, which is at the greatest distance from the Electric, ought to be made larger than the rest, as the strongest exertion of the electric fluid, in escaping from the Conductor, is always at that end.

It has been constantly observed, that the larger the prime Conductor is, the longer, and denser spark can be drawn from it; and the reason of this is, that the quantity of Electricity, discharged in a spark, is nearly proportional to the size of the Conductor; on this account the prime Conductor is now made much larger, than what was formerly used. Its size, however, may be so large, that the dissipation of the Electricity from its surface, may be greater than what the Electric can supply; in which case so large a Conductor would be nothing more than an unwieldy, and disagreeable incumbrance.

Before we quit the electrical Machine, it should be observed, that, besides the above-mentioned parts, it is necessary to

L have

have a strong frame to support the Electric, the rubber, and the wheel. The prime Conductor should be supported by stands with pillars of glass, or other solid Non-conductor, and not by silk strings, which admit of continual motion. In short, the machine, the prime Conductor, and any other apparatus actually used, should be made to stand as steady as possible, otherwise many inconveniences will arise.

Besides the electrical Machine, the Electrician should be provided with glass tubes of different sizes, a pretty large stick of sealing-wax, or a glass tube covered with sealing-wax, for the negative Electricity. He should at least not be without a glass tube about three feet long, and one inch and a half in diameter. This tube should be closed at one end, and at the other end should have fixed a brass cap with a stop-cock, which is useful in case it should be required to condense or rarefy the air within the tube.

The best rubber for a tube of smooth glass is the rough side of black oiled silk, especially

especially when it has some amalgam rubbed upon it; but the best rubber for a rough glass tube, a stick of baked wood, sealing-wax, or sulphur, is soft new flannel.

The instruments necessary for the accumulation of Electricity, are coated Electrics, among which, glass coated with Conductors obtains the principal place; on account of its strength it may be formed into any shape, and it will receive a very great charge. The form of the glass is immaterial with respect to the charge it will contain; its thickness only is to be considered, for the thinner it is, the higher charge it is capable of receiving; but it is at the same time more subject to be broken by the force of electric attraction; for this reason, therefore, a thin coated jar or plate may be used very well by itself, and it is very convenient for many experiments; but when large batteries are to be constructed, then it is necessary to use glass a little thicker, and care should be taken to have them perfectly well annealed. If a battery is required of no very great power, as containing about eight or nine square feet of coated glass, I should recommend to make.

use of common pint, or half-pint phials, such as apothecaries use. They may be easily coated with tin-foil, sheet-lead, or gilt-paper on the outside, and brass-filings on the inside; they occupy a small space, and, on account of their thinness, hold a very good charge. But when a large battery is required, then these phials cannot be used, for they break very easily; and for that purpose cylindrical glass jars, of about fifteen inches high, and four or five inches in diameter, are the most convenient. One large jar answers better than several small ones, because the dissipation of the electric fluid over the uncoated part is not so considerable in the former as in the latter case. But then, if a large jar breaks, the loss is much more considerable.

When glass plates or jars, having a sufficiently large opening, are to be coated, the best method is to coat them with tin-foil on both sides, which may be fixed upon the glass with varnish, gum-water, bees-wax, &c.; but in case the jars have not an aperture large enough to admit the tin-foil, and an instrument to adapt it to the surface of
the

the glass, then brass filings, such as are sold by the pin-makers, may be advantageously used, and they may be stuck with gum-water, bees-wax, &c. but not with varnish, for this is apt to be set on fire by the discharge, as will appear in the latter part of this work. Care must be taken that the coatings do not come very near the mouth of the jar, for that will cause the jar to discharge itself. If the coating is about two inches below the top, it will in general do very well; but there are some kinds of glass, especially tinged glass, that, when coated and charged, have the property of discharging themselves more easily than others, even when the coating is five or six inches below the edge*. There is another sort of glass, like that of which Florence flasks are made, which, on account of some unvitriified particles in its substance, is not capable of holding the least charge; on these accounts, therefore, whenever a great number of jars

* When a jar discharges itself, the electric fluid runs from the inside to the outside coating over the surface of the glass, where it leaves an indelible mark all along its path, which is mostly in a zig-zag form.

are to be chosen for a large battery, it is advisable to try some of them first, so that their quality and power may be ascertained.

Electricians have often endeavoured to find some other Electric, which might answer better than glass for this purpose, at least be cheaper; but, except FATHER BECCARIA'S method, which may be used very well, I do not find that any remarkable discovery has been made relating to this point.

FATHER BECCARIA took equal quantities of very pure colophonium, and powder of marble sifted exceedingly fine, and kept them in a hot place for a considerable time, where they became perfectly free from moisture; he then mixed them, and melted the composition in a proper vessel over the fire, and when melted poured it upon a table, upon which he had previously stuck a piece of tin-foil, reaching within two or three inches of the edge of the table; this done, he endeavoured with a hot iron to spread the mixture all over the table as equally as possible,

possible, and to the thickness of one tenth of an inch; he afterwards coated it with another piece of tin-foil, reaching within about two inches of the edge of the mixture; in short, he coated a plate of this mixture like a plate of glass. This coated plate, from what he says, seems to have had a greater power than a glass plate of the same dimensions, even when the weather was not very dry: and, if it is not subject to break very easily by a spontaneous discharge, I think it may be very conveniently used; for it doth not very readily attract moisture, and consequently may hold a charge of Electricity better, and longer, than glass: besides, if broken, it may be repaired by a hot iron; but glass, when broke, can never be repaired.

When a jar, a battery, or in general a coated Electric, is to be discharged, the operator should be provided with an instrument called the discharging Rod, which consists of a metal rod sometimes straight, but more commonly bended in the form of a C: they are made also of two joints, so as to open like a kind of compasses. This rod

is furnished with metal knobs at its extremities, and has a non-conducting handle, generally of glass or baked wood, fastened to its middle. When the operator is to use this instrument, he holds it by the handle, and, touching one of the coated sides of the charged Electric with one knob, and approaching the other knob to the other coated side, or some conducting substance communicating with it, he completes the communication between the two sides, and discharges the Electric.

The instruments to measure the quantity, and ascertain the quality of Electricity, are commonly called *Electrometers*; and they are of four sorts, 1st. the single Thread, 2d. the Cork, or Pith-balls, 3d. the Quadrant, and 4th. the discharging Electrometer *. But a particular description of the same will be found in the third chapter of this work.

* The second sort of Electrometer, i. e. the cork-balls Electrometer, was invented by Mr. CANTON; the discharging Electrometer was invented by Mr. LANE; and another, on a different principle, by Mr. KINNERSLEY: and the quadrant Electrometer, which is of latest invention, is a contrivance of Mr. HENLY.

Besides the apparatus above described, there are several other instruments useful for various experiments, but these will be described occasionally. The Electrician, however, ought to have by him not only a single coated jar, a single discharging rod, or in short, only what is necessary to perform the common experiments; but he should provide himself with several plates of glass, with jars of different sizes, with a variety of different instruments of every kind, and even tools for constructing them; in order that he may readily make such new experiments, as his curiosity may induce him to try, or that may be published by other ingenious persons, who are pursuing their researches in this branch of philosophy.

C H A P. II.

The description of some particular electrical Machines.

IN this chapter I shall present the reader with the particular description of some electrical Machines, which, I think, will be very acceptable after the general account of their construction, which has already been given. The first of these is that described by Dr. PRIESTLEY, in his History of Electricity *; where a drawing of the same may be seen, and which, on account of its extensive use, may be deservedly called a universal electrical Machine.

The basis of this machine consists of two oblong boards, which are kept in a situation parallel to one another, about four inches asunder, by two small pieces of board properly adapted to that purpose. These boards, when set horizontally upon a table, and there fixed by fastening the lower of them with iron cranks, form the support of two perpendicular pillars of

* Part V. Sec. II.

baked wood, and of the rubber of the machine. One of the pillars, together with the spring supporting the rubber, slides in a groove, which reaches almost the whole length of the upper board, and, by means of screws, may be placed at any required distance from the other pillar, which is fixed, being let through a mortice in the upper board, and strongly fastened to the lower. In these two pillars are several holes for the admittance of the spindles of different globes, and, as they may be situated at any distance from one another, they may be adapted to receive not only globes, but also cylinders, or spheroids, of different sizes. In this machine, says Dr. PRIESTLEY, more than one globe or cylinder may be used at once, by fixing them one above the other in the different holes of the pillars; and by adapting to each a proper pulley, they may be whirled all at once, and their power united, in order to increase the Electricity*; but in this construction I do not

* When several globes are used at once, and their power is united, it has been found by experiment, that the Electricity does not increase in proportion to their number,

not think that different rubbers can be conveniently applied to them all; which is a capital imperfection.

“ The rubber consists of a hollow piece
 “ of copper, filled with horse-hair, and
 “ covered with a basil skin. It is sup-
 “ ported by a socket, which receives the
 “ cylindrical axis of a round and flat piece
 “ of baked wood, the opposite part of
 “ which is inserted into the socket of a
 “ bent steel spring. These parts are easily
 “ separated, so that the rubber, or the piece
 “ of wood that serves to insulate it, may
 “ be changed at pleasure. The spring
 “ admits of a two-fold alteration of posi-
 “ tion. It may be either slipped along the
 “ groove, or moved in the contrary direc-
 “ tion” (the groove being wider than
 the screw which fastens the spring), “ so
 “ as to give it every desirable position with

number, although it is more than what may be produced by a single globe. However, as the friction, and the difficulty of working the machine, increases in proportion to the number of globes or cylinders, so I think that one good large cylinder is preferable to many of them.

“ respect to the globe or cylinder ; and it
 “ is, besides, furnished with a screw,
 “ which makes it press harder or lighter,
 “ as the operator choofes.”

The wheel of this machine is fixed to the table ; it has several grooves, for admitting more strings than one, in case that two or three globes or cylinders are used at a time ; and as it is disengaged from the frame of the machine, the latter may be screwed at different distances from the former, and thus suited to the variable length of the string.

The prime Conductor is of hollow copper, made in the shape of a pear, situated with its neck upwards, and with its bottom or rounder part upon a stand of baked wood ; and an arched wire proceeds from its neck, having an open ring at its end, in which some small pointed wires are hung, that by playing lightly upon the Electric collect the electric fluid from it. This form of prime conductor is, however, very improper.

This

This machine, notwithstanding that it has several imperfections, is yet a very good contrivance; but, except different globes, or cylinders, or several of those at once, are required to be used, I think a great deal of the work may be spared, and the machine might be made more simple and concise.

Next to Dr. PRIESTLEY's machine, I shall describe another, which, for its simplicity, and conciseness, makes a fine contrast with the former.

This machine consists of a circular glass plate, about one foot diameter, which is turned vertically by a winch fixed to the iron axis that passes through its middle; and it is rubbed by four cushions, each about two inches long, situated at the opposite ends of the vertical diameter.

The frame consists of a bottom board, about a foot square, or a foot long and six inches broad, which, when the machine is to be used, may be fastened by an iron crank to the table. Upon this board two other slender and smaller ones are raised,
which

which lie parallel to one another, and are fastened together at their top by a small piece of wood. These upright boards support in their middle the axis of the plate, and to them the rubbers are fastened.

The Conductor is of hollow brass, and from its extremities branches are extended, which coming very near the extremity of the glass, collect the Electricity from it.

The power of this machine is perhaps more than a person would judge by looking at it. It may be objected, that this construction will not easily admit of the rubbers being insulated, nor consequently be adapted to a great variety of experiments; but at the same time it must be allowed, that it is very portable, that it is not very liable to be out of order, and that it has a power sufficiently strong for several purposes; on which account it may be conveniently used. These machines have often been made with two parallel glass plates, and those of a considerable diameter; which plates, turning upon the same axis,

axis, are rubbed by eight rubbers.—The sparks obtained from the conductors of those machines are strong, though not very long; yet an electrical battery may be charged by one of those machines very quick, since they accumulate an astonishing quantity of electric fluid. Their principal imperfections are—the great number of rubbers that the operator must keep in proper order—the friction arising from them, which renders the turning of the machine rather hard—and lastly, the plates being subject to crack very easily.

The machine represented in fig. 1. of plate I. has all the principal improvements hitherto made, except that it is not capable of admitting different kinds, or more than one Electric, but which, indeed, it seems not to stand in need of. The electric power of such a machine, is at least equal to what may be obtained by any other construction; and at the same time its size, being neither remarkably large, nor at all inconvenient, renders it, I think, the *completest machine* hitherto contrived, and may be made of any size.

The

The frame of this machine consists of the bottom board ABC, which, when the machine is to be used, is fastened to the table by two iron cranks, one of which appears in the figure near C. Upon the bottom board are perpendicularly raised two strong wooden pillars KL, and AH, which support the cylinder, and the wheel. From one of the brass caps of the cylinder FF, an axle of steel proceeds, which passes quite through a hole in the pillar KL, and has on this side of the pillar a pulley I, fixed upon its square extremity. Upon the circumference of this pulley there are three or four grooves, in order to suit the variable length of the string *ab*, which goes round one of them, and round the groove of the wheel D. The other cap of the cylinder has a small cavity, which fits the conical extremity of a strong screw, that proceeds from the pillar H. The wheel D, which is moved by the handle E, turns round a strong axle, proceeding from almost the middle of the pillar KL.

The rubber G of this machine is on each end two or three inches shorter than the
M cylinder

cylinder (*i. e.* the cylinder exclusive of the necks), and it is made to rub about one tenth part of the cylinder's circumference, or rather less; it consists of a thin quilted cushion of silk, stuffed with hair, and fastened by silk strings upon a piece of wood, which is properly adapted to the surface of the cylinder. And to the lower extremity of the cushion, or rather of the piece of wood to which the cushion is tied, a piece of leather is fastened, which is turned over the cushion, *i. e.* stands between it and the surface of the cylinder, and to the extremity of which a piece of silk or oiled silk is fastened, which covers almost all the upper part of the cylinder. Upon this leather, which reaches from the lower to almost the upper extremity of the cushion, some of the above-described amalgam is to be worked, so as to be forced as much as possible into its substance: if mosaic gold is to be tried, then the leather should be new, and whereon no other amalgam has been put. This rubber is supported by two springs, screwed to its back, and from which it may be easily unscrewed, when occasion requires it. The two springs proceed from the wooden
cap

cap of a strong glass pillar*, perpendicular to the bottom board of the machine. This pillar has a square wooden basis, that slides in two grooves in the bottom board ABC, upon which it is fastened by a screw. In this manner the glass pillar may be fastened at any required distance, and in consequence the rubber may be made to press harder or lighter upon the cylinder. The rubber in this manner is perfectly insulated; and, when insulation is not required, a chain with a small hook may be hanged to it, so as to have a regular communication with the piece of leather; the chain then falling upon the table, renders the rubber unin-
sulated.

Fig. 2. represents the prime Conductor AB belonging to this machine. This is

* This glass pillar, as well as the glass feet of insulating stools in general, should be covered with varnish, or rather with sealing-wax, otherwise they insulate very imperfectly, on account of the moisture that they attract from the air, especially in damp weather. It must be observed, that sealing-wax dissolved in spirits of wine, may be used very well for this purpose; but to cover a piece of glass with sealing-wax, by rubbing a stick of it upon the surface of the glass when hot, answers far better.

of hollow brass, and is supported by two glass pillars varnished, that by two brass sockets are fixed in the board CC. This Conductor receives the electric fluid through the points of the collector L, which are set at about half an inch distance from the surface of the cylinder of the machine.

If the handle E, fig. 1, of the wheel, be turned (and on account of the rubber it should be turned always in the direction of the letters *a b c*) this machine, standing in the situation that is represented in the figure, will give positive Electricity, *i. e.* the prime Conductor will be electrified positively, or overcharged with electric fluid; for by the action of rubbing, the cylinder pumps, as it were, the fluid from the rubber, and every other body properly connected with it, and gives it to the prime Conductor. But if a negative Electricity is required, then the chain must be removed from the rubber and hung to the prime Conductor; for in this case the Electricity of the prime Conductor will be communicated to the ground, and the rubber remaining

maining insulated, will appear strongly negative. Another Conductor, equal to the Conductor AB, fig. 2, may be connected with the insulated rubber, and then the operator may obtain as strong negative Electricity from this, as he can positive from the Conductor AB.

I shall, lastly, give a short description of the machine lately contrived by Mr. E. NAIRNE, F. R. S. which is principally adapted for medical Electricity, and for that purpose it answers exceedingly well, as with it any degree of electric power may be used with the utmost facility. Fig. 8 of plate II. represents this machine, the principal parts of which are the glass Cylinder and the two Conductors, all lying parallel. The Cylinder, which is generally about 7 inches in diameter, is furnished with wooden caps, and turns in two wooden pieces, which are cemented on the tops of two strong glass pillars B B. These pillars are made fast into the bottom board of the machine, which is fastened to the table by means of a crank. On the under part of the bottom board grooves are formed, through which the

pieces FF slide. These pieces support the Conductors upon the strong glass pillars DD; and in order to let the Conductors be placed farther or nearer to the glass cylinder, the pieces FF may be moved in or out, and may be steadied, by means of the screw nuts LL. The rubber is fastened to the Conductor R, and it consists of a stuffed leather cushion, to the under part of which a piece of silk is glued, which being turned over the surface of the cushion, *viz.* between it and the glass, goes over the Cylinder, and almost reaches the pointed wires which are fixed on the other Conductor for the purpose of collecting the electric fluid from the Cylinder.

The Conductors are of tin covered with black lacquer, and each contains a coated glass jar, and likewise a small coated tube or small jar, which are seen when the caps NN are removed. A knob O is fixed to each Conductor, to which a chain may be occasionally suspended, in order to have a positive or negative Electricity by communicating one of the Conductors with the earth.

The longest part of the winch C, by which the Cylinder is turned, is of glass.

Thus it appears that every part of this machine is insulated, *viz.* not only the Conductors with the rubber, but even the glass Cylinder and its caps; by which means the electric fluid that is accumulated on the Cylinder is least likely to be dissipated; which, joined to the excellent workmanship and execution of every part, renders this machine very powerful; and I must confess, that I never saw an electrical machine, upon any other principle, have so much power as one of this construction, and of equal dimensions.

To this machine Mr. NAIRNE has adapted some flexible conducting joints, a discharging electrometer, and several other instruments necessary to answer every purpose of medical Electricity; especially the very small shocks may be administered, by means of the jars inserted into the Conductors, with great facility, and almost to an imperceptible degree. For farther particulars

M 4 respecting

respecting the construction and use of this excellent machine, and its apparatus, I must refer the reader to Mr. NAIRNE's own description.



H. A. P. III.

The particular Description of some other necessary Parts of the electrical Apparatus.

FIG. 4 represents a stand supporting the electrometers DD CC. B is the basis of it, made of common wood. A is a pillar of wax, glass, or baked wood. To the top of the pillar, if it be of wax or glass, a circular piece of wood is fixed; but if the pillar be of baked wood, that may constitute the whole. From this circular piece of wood proceed four arms of glass, or baked wood, suspending at their ends four electrometers, two of which, DD, are silk threads about eight inches long, suspending each a small downy feather at its end.

end. The other two electrometers, CC, are those with very small balls of cork, or of the pith of elder; and they are constructed in the following manner:—*ab* is a stick of glass about six inches long, covered with sealing-wax, and shaped at top in a ring: from the lower extremity of this stick of glass proceed two fine linen threads* *cc*, about five inches long, each suspending a cork, or pith-ball *d*, about one-eighth of an inch in diameter. When this electrometer is not electrified, the threads *cc* hang parallel to each other, and the cork-balls are in contact; but when electrified, they repel one another, as represented in the figure. The glass stick *ab* serves for an insulating handle, by which the electrometer may be supported, when it is used without the stand AB.

Another species of the above electrometer is represented in fig. 3; which consists of a linen thread, having at each end a small cork-ball. This electrometer is suspended by the middle of the thread on any

* These threads should be wetted in a weak solution of salt.

Conductor proper for the purpose, and serves to shew the kind and quantity of its Electricity.

Fig. 7 represents Mr. HENLY's quadrant electrometer, fixed upon a small stand, from which it may be occasionally separated, and fixed upon the prime Conductor, or in any other place, at pleasure. This electrometer consists of a perpendicular stem, formed at the top like a ball, and furnished at its lower end with a brass ferrule, by which it may be fixed in one of the holes of the prime Conductor, or in its proper stand, as occasion requires. To the upper part of the stem, or pillar, a graduated ivory semicircle is fixed, about the middle of which is a brass arm, which contains a pin, or the small axis of the index. The index consists of a very slender stick, which reaches from the center of the graduated semicircle to the brass ferrule, and at its lower extremity is fastened a small cork-ball, nicely turned in a lathe. FR. BECCARIA recommends to inclose the upper part of the index of this electrometer between two semicircles.

The

The properest wood, for the purpose of making the pillar and index of this electrometer, is box, and this pillar and index should be well rounded, and made as smooth as possible. When this electrometer is not electrified, the index hangs parallel to the pillar, as in fig. 7; but when it is electrified, the index recedes more or less, according to the quantity of Electricity, from the stem; as represented on the prime Conductor E, fig. 2.

The main of Mr. LANE's discharging Electrometer, consists in a brass ball about one inch and a half in diameter, screwed to a brass graduated rod, and adapted to a proper frame, so that it may be set at any required distance from the prime Conductor, or the knob of an electric jar. The principal use of this electrometer is to let a jar discharge by itself through any proper circuit, without using any discharging rod, or removing any part of the apparatus; and to give shocks nearly of the same strength. Suppose, for instance, that the above-mentioned brass ball be set at half an inch distance from the prime Conductor, and that a
coated

coated jar be situated so as to touch the prime Conductor with its knob, and to have its outside coating communicating with the above-mentioned brass ball. Now it is evident that the circuit, from the outside to the inside of the jar, is interrupted only between the prime Conductor and the brass ball, which lie half an inch asunder; therefore, when the jar is charging, and the charge is become so high as to strike through half an inch of air, the jar will discharge itself, and, by keeping the brass ball at the same distance from the prime Conductor, and charging the jar successively, the shocks will be of the same strength.

This electrometer is subject to an inconvenience; which is, that the surface of the brass ball is sometimes deprived of its smoothness by the force of the explosion; in which case it is necessary to polish it again, otherwise the instrument is useless; though this never happens when small shocks are used. An electrometer of this kind, though not exactly like the original one, is now commonly used by the practitioners of medical electricity, and is delineated in fig. 6, of Plate II.

It consists of a glass arm D, which proceeds from the wire of the jar F, and to the extremity E of which a spring socket is cemented, through which a wire passes, which is furnished with a knob B, towards the knob A of the jar, and with an open ring C at its other extremity. Now, as this wire may be slid backwards and forwards, the knob B may be put at any required distance from the knob A, as far as the construction of the instrument will allow. The wire BC is generally marked with divisions, which shew the distance of the two knobs, when the wire is so situated, as that the required division coincides with the edge of the spring socket; as, for instance, one tenth, or one quarter of an inch, &c. When the jar F is set against the prime Conductor G, as represented in the figure, suppose that the ball B is set at the distance of $\frac{1}{10}$ of an inch from the ball A, and that a wire be fixed from the electrometer's ring to the outside coating of the jar, as shewn by the dotted line CK; then, when the machine is put in motion, the discharge of the jar, as soon as this becomes sufficiently charged, will be made between the knobs AB, and through the

the wire CK ; and it is evident that these discharges will be of the same strength, as long as the distance between AB remains the same.

Fig. 5 of Plate I. represents Mr. HENLY's universal discharger, which is of a very extensive use, and is composed of the following parts :—A is a flat board fifteen inches long, four inches broad, and one thick, or thereabouts, which forms the basis of the instrument. BB are two glass pillars, cemented in two holes upon the board A, and furnished at their top with brass caps, each of which has a turning joint, and supports a spring tube, through which the wire DC slides : each of these caps is composed of three pieces of brass, connected so, that the wire DC, besides its sliding through the socket, has two other motions, *viz.* an horizontal and a vertical one. Each of the wires DC, DC, is furnished with an open ring at one end, and at the other end has a brass ball D, which, by a short spring socket, is slipped upon its pointed extremity, and may be removed from it at pleasure. E is a strong circular piece of wood, five inches in

in diameter, having, on its surface, a slip of ivory inlaid, and furnished with a strong cylindrical foot, which fits the cavity of the socket F, which is fastened in the middle of the bottom board, and has a screw G, which serves to fasten the foot of the circular board E at any required height. H is a small press belonging to this instrument; it consists of two oblong pieces of board, which may be pressed against each other by means of two screws *a a*: the lower of these boards has a cylindrical foot equal to the foot of the circular board E. When this press is to be used, it is fixed into the socket F, in the place of the circular board E, which must, in that case, be removed.

Fig. 11 is an electric jar, coated with tin-foil on the inside and outside, within three inches of the top of the cylindrical part of the glass, having a wire with a round brass knob A at its extremity. This wire passes through the cork * D, that stops the mouth of the jar, and, at its lower

* When corks are used to stop electric jars, they should be made very dry, and dipped in melted bees-wax, or varnished.

end,

end, is bended so as to touch the inside coating in several places.

Fig. 10 represents a battery composed of sixteen jars, coated in the inside and outside with tin-foil; which all together contain about twelve feet of coated glass. About the middle of each of these jars is a cork that sustains a wire, which at the top is fastened round, or soldered to the wire E, knobbed at each end, which connects the inside coatings of four jars; and by the wires FFF the inside coatings of all the sixteen jars are connected together. Each of the wires F has a ring at one end, through which one of the wires E passes, and at the other end has a brass knob. If the whole force of the battery is not required, one, two, or three rows of jars may be used at pleasure; for as each of the wires FFF is moveable round the wire E, which passes through its ring, and rests upon the next wire E, it may be easily removed from that, and turned upon the contrary wire E; and thus the communication between one row of jars and another may be discontinued at pleasure. See the figure.

The

The square box that contains these jars is of wood lined at the bottom with sheet-lead or tin-foil, and has two handles on two opposite sides, by which it may be easily removed. In one side of the box is a hole, through which an iron hook B passes, which communicates with the metallic lining of the box, and consequently with the outside coating of all the jars. To this hook is fastened a wire, the other end of which is connected with the discharging-rod.

The discharging-rod consists of a glass handle A, and two curved wires BB, which move by a joint C, fixed to the brass cap of the glass handle A. The wires BB are pointed, and the points enter the knobs DD, to which they are screwed, and may be unscrewed from them at pleasure. By this construction we have the opportunity of using the balls or the points, as occasion requires; and as the wires are moveable by the joint C, they may be adapted to smaller or larger jars at pleasure.

N

The

The battery, represented in the plate, is a small one in comparison to those now frequently used, and much too weak for the purpose of some experiments, hereafter to be described. But I thought it sufficient to give an idea of its construction; and, when a large battery is to be constructed, I would recommend rather to make two, three, or more small ones, as represented in the plate, than a single large battery, which is heavy, and, on several accounts, inconvenient. The force of several small batteries may be easily united by a wire or a chain, and thus they may be made to act like a large one.

F in fig. 2. is a circular brass plate hung on the prime Conductor by a chain, and resting in an horizontal position. Underneath this, there is another plate P parallel, and equal to the former (but it would be better if it was a little larger), which is supported by a stand H of brass, having also a socket to receive the foot of the plate, and a screw G to fix it at different distances.

D in fig. 2. is a fly made of small brass wires, fixed in a cap of brass also; which is to be put upon the pointed wire K, that is screwed to the prime conductor, upon which it must stand in equilibrio, like the needle of a compass. The other ends *a*, *b*, *c*, *d* of the wires are pointed, and bent all one way.

N. B. Whenever hereafter I mention the prime Conductor, I mean the prime Conductor naked, that is, without the parallel brass plates F P, without the fly D and its supporting pin K, without the electrometers E, and even without the knobbed rod IB, which is screwed to it occasionally; except the contrary is expressed.

It is highly requisite for an Electrician to have by him several insulating stools, or stands, they being very necessary for several experiments. The best materials to construct these are glass covered with sealing-wax. Baked wood may also be used*.

A large

* The wood should be baked very well, even till it becomes quite brown, it then being in the best state for

large stool, proper to insulate a chair upon, or two or three persons standing, may be made with a strong board, about two feet and a half square, and may be supported by four feet of glass, about eight inches long. But small stands are better made with one foot or pillar, and all of baked wood or glass, without any conducting substance in their construction. Wine-glasses, either varnished, or in part covered with sealing-wax, answer this purpose very well.

insulation; and to defend it from moisture, it must be varnished as soon as it comes out of the oven, or else boiled in linseed-oil; but in this case, after boiling, it should be made hot again, and then it is fit for use.

CHAP. IV.

Practical Rules concerning the Use of the electrical Apparatus, and the performing of Experiments.

IT often happens that young Electricians are at a loss to assign the reason, why some experiments do not succeed with them, as described in the Treatises on Electricity. Sometimes they are in possession of very good instruments, but, by reason of some circumstance or other unattended to, they are quite useless in their hands. This indeed can be remedied by nothing but practice, and it is by long use, that the Electrician, as well as the Practitioner in any art or science, becomes so good an Operator, as to use his instruments to the best advantage. A few rules are however very necessary, to guide him in his operations; and although these alone are insufficient to make a person a complete practical Electrician, yet, when accompanied with the actual management of the apparatus, they fa-

cilitate the use of it, and render the performance of the experiments more accurate and expeditious.

The first thing that the young Electrician should observe, is, the preservation, and care, of his instruments. The electrical machine, the coated jars, and in short every part of the electrical apparatus, should be kept clean, and as free as possible from dust, and moisture.

When the weather is clear, and the air dry, especially in clear and frosty weather, the electrical machine will always work well. But when the weather is very hot, the electrical machine is not so powerful: nor in damp weather, except it be brought into a warm room; and the cylinder, the stands, the jars, &c. be made thoroughly dry.

Before the machine be used, the cylinder should be first wiped very clean with a soft linen cloth, that is dry, clean, and warm; and afterwards with a clean hot flannel, or an old silk handkerchief; this done, if the
winch

winch be turned, when the prime Conductor, and other instruments, are removed from the electrical machine, and the knuckle be held at a little distance from the surface of the cylinder, it will be soon perceived that the electric fluid comes like a wind from the cylinder to the knuckle, and, if the motion be a little continued, sparks, and crackling will soon follow. This indicates that the machine is in good order, and the Electrician may proceed to perform his experiments. But if, when the winch is turned for some time, no wind is felt upon the knuckle, then the fault is, very likely, in the rubber; and to remedy that, use the following directions:—By unscrewing the screws on the back of the rubber, remove it from its glass pillar, and keep it a little near the fire, so that its silk part may be dried; take now a dry piece of mutton-suet, or a little tallow from a candle, and just pass it over the leather of the rubber, then spread a small quantity of the above-described amalgam over it, and force it as much as possible into the leather. This done, replace the rubber upon the glass pillar; let the glass cylinder be wiped

once more, and then the machine is fit for use. In Mr. NAIRNE's machine no amalgam is put upon the rubber; but whilst the clean rubber is on, and the cylinder turning, a piece of leather with some amalgam spread on it is applied for a few seconds to the under part of the cylinder, the doing of which will bring a sufficient quantity of amalgam to the rubber.

Sometimes the machine will not work well, because the rubber is not sufficiently supplied with electric fluid, which happens when the table upon which the machine stands, and to which the chain of the rubber is connected, is very dry, and consequently in a bad conducting state. Even the floor and the walls of the room are, in very dry weather, bad Conductors, and they cannot supply the rubber sufficiently. In this case, the best expedient is, to connect the chain of the rubber, by means of a long wire, with some moist ground, a piece of water, or with the iron-work of the water pump; by which means the rubber will be supplied with as much electric fluid as is required.

It

It must be also remarked, that when the cylinder is very hot, as above 110° , it will not act well.

When a sufficient quantity of amalgam has been accumulated upon the leather of the rubber, and the machine does not work very well, then, instead of putting more amalgam, it will be sufficient to take the rubber off, and to scrape a little, that which is already upon the leather.

It will be often observed, that the cylinder, after being used some time, contracts some black spots, occasioned by the amalgam, or some foulness of the rubber, which grow continually larger, and greatly obstruct its electric power. These spots must be carefully taken off, and the cylinder must be frequently wiped, in order to prevent its contracting them.

In charging electric jars in general, it must be observed, that not every machine will charge them equally high. That machine, whose electric power is the strongest, will always charge the jars highest. If
the

the coated jars, before they are used, be made a little warm, they will receive, and hold the charge the better.

If several jars are connected together, among which there is one, that is apt to discharge itself very soon, then the other jars will also soon be discharged with that; although they may be capable of holding a very great charge by themselves. When electric jars are to be discharged, the Electrician must be cautious lest, by some circumstance not adverted to, the shock should pass through any part of his body; for an unexpected shock, though not very strong, may occasion several disagreeable accidents. In making the discharge, care must be taken that the discharging-rod be not placed on the thinnest part of the glass, for that may cause the bursting of the jar.

When large batteries are discharged, jars will be often found broken in it, which burst at the time of the discharge. To remedy this inconvenience, Mr. NAIRNE says he has found a very effectual method; which is, never to discharge the battery through a
good

good Conductor, except the circuit be at least five feet long. Mr. NAIRNE adds, that ever since he made use of this precaution, he has discharged a very large battery near a hundred times, without ever breaking a single jar, whereas before he was continually breaking them. But here it must be considered, that the length of the circuit weakens the force of the shock proportionably; the highest degree of which is in many experiments required.

When a coated phial is cracked, either by a spontaneous discharge, or by any other accident, I remove the outside coating from the fractured part, and then make it moderately hot by holding it to the flame of a candle, and whilst it remains hot I apply burning sealing-wax to the part, so as to cover the fracture entirely; taking care that the thickness of the wax is rather more than the thickness of the glass. Lastly, I cover all the sealing-wax, and also part of the surface of the glass beyond it, with a composition made with four parts of bees-wax, one of rosin, one of turpentine, and a very little oil of olives; which composition

tion I spread upon a piece of oiled silk, and apply it in the manner of a plaister. With this method I have repaired several broken phials so effectually, that after being frequently charged, they were at last broken by a spontaneous discharge, but in a different part of the glass *.

It is adviseable, when a jar, and especially a battery, has been discharged, not to touch its wires with the hand, before the discharging-rod be applied to its sides a second, and even a third time; as there generally remains a residuum of the charge †, which is sometimes very considerable.

* Here it is proper to remark, that when jars, or glass in general, that is coated for the purpose of charging and discharging, is in any manner covered with cement or sealing-wax, it breaks more easily by a spontaneous discharge; and it is very remarkable, that the fracture generally lies on the limits of the cement.

† This residuum is in great measure occasioned by the Electricity, that, when the jar is charging, spreads itself over the uncoated part of the glass near the coating, which will not be discharged at first, but gradually returns to the coating after the first discharge.

When

When any experiment is to be performed, which requires but a small part of the apparatus, the remaining part of it should be placed at a distance from the machine, the prime Conductor, and even from the table, if that is not very large. Candles, particularly, should be placed at a considerable distance from the prime Conductor, for the effluvia of their flames carry off much of the electric fluid.

Lastly, the young Electrician should be cautioned not to depend on first appearances in Electricity. A new phenomenon may justly excite his curiosity : it is laudable to remark it, and to pursue the hint ; but at the same time even the doubtful assertion of a new fact should never be made, till after a number of similar and concurring experiments. Electricity is a science that often deceives the senses, and the most experienced Electrician frequently finds himself mistaken in things, which perhaps he may have before considered as the most certain.



C H A P. V.

*Experiments concerning electric Attraction
and Repulsion.*

EXPERIMENT I.

The electrified Cork-ball Electrometer.

WHEN the electrical machine is put in order, and the prime Conductor is set so, that the points of the collector are about half an inch from the surface of the cylinder, fix at the end of the prime Conductor the knobbed rod I B fig. 2. and hang on it the electrometer with the cork-balls fig. 3. The balls will now touch one another, the threads hanging perpendicularly, and parallel to each other. But if the cylinder of the machine be whirled by turning the winch E, then the cork-balls will repel one another, and more, or less, according as the Electricity is more or less powerful.

In

In this experiment, the glass cylinder extracting the electric fluid from the rubber, throws it upon the pointed wires of the collector, and in consequence upon the prime Conductor, and the electrometer; which are all connected together: and as bodies overcharged with electric fluid will always repel each other, so the cork-balls must repel each other.

If the electrometer be hung to a prime Conductor negatively electrified, *i. e.* connected with the insulated rubber of the machine, the cork-balls will also repel each other; for bodies, undercharged, will repel each other, as well as bodies overcharged with electric fluid.

If, in this state of repulsion, the prime Conductor is touched with some conducting substance not insulated, the cork-balls will immediately come together; for the electric fluid superinduced upon the prime Conductor, and the electrometer communicating with it, will be carried away to the ground by that conducting body; so that in this case the prime Conductor can never be over-

overcharged: nor can it be undercharged; if connected with the rubber; for its deficiency of fluid is supplied through that conducting body, with which it has been touched. But if, instead of the conducting substance, the prime Conductor is touched with an electric, as for instance a stick of sealing-wax, a piece of glass, &c. then the cork-balls will continue to repel each other; because the electric fluid cannot be conducted through that electric: hence we have an easy method of determining what bodies are Conductors, and what electrics*.

This electrical repulsion is also shewn by the quadrant electrometer, with a large downy feather, or the like; for if these be connected with the prime Conductor, and the winch be turned, the electrometer will raise its index, and the feather, by the divergency of its down, will appear swelled in a beautiful manner.

*. This method in gross will do very well; but when the conducting power of fluids or some other bodies, and the degree of that power, is to be ascertained, then recourse must be had to other means, more nice and accurate.

EXPERIMENT II.

Attraction and Repulsion of light Bodies.

Connect with the prime Conductor the two parallel brass plates F, P, as represented in fig. 2. at about three inches distance from one another, and upon the lower plate put any kind of light bodies, as bran, bits of paper, bits of leaf-gold, &c.; then work the machine, and the light bodies will soon move between the two plates, leaping alternately from one to the other with great velocity. If, instead of bran, or irregular pieces of other matter, small figures of men or other things cut in paper, and painted, be put upon the plate, they will generally move in an erect position, but will sometimes leap one upon another, or exhibit different postures, so as to afford a pleasing spectacle to an observing company.

In this experiment, both the attraction and repulsion of Electricity are observed at the same time: for when the upper plate

O

F, which

F, which communicates with the prime Conductor, is electrified, the small bodies placed upon the lower plate, together with that plate, by being within the sphere of action of the electrified upper plate, become actually possessed of a contrary Electricity, leaving their proper quantity of fluid in the lower plate, or the other conducting bodies, that communicate with it. But bodies differently electrified attract each other; therefore the plate F attracts those light bodies. Now, as soon as these bodies touch the plate F, they become instantly possessed of the same Electricity with the plate, and will therefore be immediately repelled to the lower plate, which is actually electrified with the contrary Electricity, and by touching the light bodies, assists in repelling them again to the upper plate; and thus the plates continue to act upon the light bodies alternately.

That the light bodies cannot be attracted by the upper plate, except they become first possessed of a contrary Electricity, may be observed as follows:—Put the said light bodies upon a clean, and dry pane of glass; then

then take off the brass plate P, with its stand G, and in its stead put the pane of glass, holding it by one corner; this done, let the wheel of the machine be turned, and you will see that the light bodies are not attracted by the brass plate F; for in this case they have no opportunity of parting with their proper quantity of fluid, and consequently cannot acquire the contrary Electricity. But if to the under side of the pane of glass, on which the light bodies are placed, a finger or any other conductor be presented, the light bodies will be instantly attracted by the plate F, and will leap between the glass and plate, in the same manner as between the two plates; for these bodies now deposit their fluid upon the upper surface of the glass plate, whilst the under surface deposits its fluid upon the finger, or other conductor, that has been brought near it*. If this experiment be

* If the above experiment be made with a prime Conductor negatively electrified, the effect will be the same, only the Electricities of the plates are reversed; i. e. the upper plate is electrified negatively, and the under plate, by being in the atmosphere of the upper one, is positively electrified.

continued, the glass will soon be charged*.

EXPERIMENT III.

The Flying-feather, or Shuttle-cock.

The phenomena of electric attraction and repulsion may be represented also with a glass tube, or a charged bottle, and some of them in a manner more satisfactory than with the machine.

Take a glass tube (whether smooth, or rough, is not material), and after having rubbed it, let a small light feather be let out of your fingers at the distance of about eight or nine inches from it. This feather will be immediately attracted by the tube, and will stick very close to its surface for about two or three seconds, and sometimes longer; after which time it will be repelled, and if the tube be kept under it, the feather will continue floating in the air at

* Electric attraction and repulsion takes place also within a vacuum, made by means of common air-pumps.

a con-

a considerable distance from the tube, without coming near it again, except it first touches some conducting substance; and if you manage the tube dexterously, you may drive the feather through the air of a room at your pleasure.

The reason of this experiment is obvious; for when the feather is electrified, it cannot approach the tube again, except it first touches some conducting body, because it cannot part with its Electricity when floating in the air, and therefore cannot acquire a contrary Electricity: consequently it must remain in a state incapable of being again attracted by the excited tube.

If it be asked, Why, when the feather is at first attracted by the tube, it sticks for so considerable a time to its surface before it is repelled? the answer is, That the feather being an electric, requireth some time before it acquires any considerable quantity of Electricity.

There is a remarkable circumstance attending this experiment, which is, that if

the feather be kept at a distance from the tube by the force of electric repulsion, it always presents the same part towards the tube:—You may move the excited tube about the feather very swiftly, and yet the same side of the feather will always be presented to the tube. The reason of this phenomenon is, that the equilibrium of the electric fluid in the parts of the feather, being once disturbed, cannot easily be restored; because the feather is an electric, or at least a very bad Conductor. When the feather has acquired a quantity of Electricity from the tube, it is plain, that by the action of the excited tube, that super-induced Electricity will be in the greatest part forced on that side of the feather which happens to be at first the farthest from the tube; hence that part will always afterward be repelled the farthest.

This experiment may be agreeably varied in the following manner:—A person may hold in his hand an excited tube of smooth glass, and another person may hold an excited rough glass tube, a stick of sealing-wax, or in short another electric negatively

negatively electrified, at about one foot and a half distance from the smooth glass tube: a feather now may be let go between these two differently-excited electrics, and it will leap alternately from one electric to the other; and the two persons will seem to drive a shuttle-cock from one to the other, by the force of Electricity.

EXPERIMENT IV.

The small insulated Body.

Tie a small body, as for instance a light piece of cork, to a silk thread about eight inches long, and holding the thread by its end, let the small body hang at the distance of about eight inches from the side of the prime Conductor electrified. This small body, if the electrization of the Conductor is not strong, will not be attracted; for, being insulated, it cannot, by depositing its fluid upon, or receiving it from, another body (when the prime Conductor is electrified negatively), become contrarily electrified. But if a finger or any conducting substance be presented to

the side of the small body which is farthest from the prime Conductor, then the small body will immediately move toward the prime Conductor; for it has deposited its own fluid upon, or acquired some (in case the Conductor is negatively electrified) from the body presented to it; and when this body has touched the prime Conductor, it will be instantly repelled from it, on account of the repulsion existing between bodies possessed of the same kind of Electricity.

Indeed, if this insulated body be very near to the prime Conductor, or the prime Conductor strongly electrified, then the small body will be attracted without presenting to it any conducting substance; but in this case its natural quantity of electric fluid will be either repelled into the contiguous air, or crowded on the part of the body which is farthest from the prime Conductor, if the Conductor is electrified *positively*; but if it is electrified *negatively*, then the additional quantity of fluid, necessary to render the small body overcharged, will be acquired from the air, or

the

the natural fluid belonging to that body will be all crowded on that side of it, which is nearest to the prime Conductor.

If this small body, instead of the silk, be suspended by a linen thread, it will be attracted at a much greater distance, than in the other case; for now the electric fluid will easily be conducted by the thread, passing upwards, or downwards, according as the prime Conductor is electrified, *viz.* negatively or positively.

EXPERIMENT V.

The electric Well.

Place upon an electric stool a metal quart mug, or some other conducting body nearly of the same form and dimension; then tie a short cork-ball electrometer, of the kind represented fig. 3 *, at the end of a silk thread proceeding from the ceiling of the room, or from any other proper support,

* Instead of the electrometer, there may be used any other kind of small conducting body; but that seems best adapted to such experiments.

so that the electrometer may be suspended within the mug, and no part of it may be above the mouth; this done, electrify the mug, by giving it a spark with an excited electric or otherwise, and you will see that the electrometer, whilst it remains in that insulated situation, even if it be made to touch the sides of the mug, is not attracted by it, nor does it acquire any Electricity; but if, whilst it stands suspended within the mug, a Conductor, standing out of the mug, be made to communicate with, or only presented to it, then the electrometer acquires an Electricity contrary to that of the mug, and a quantity of it, which is proportionable to the body with which it has been made to communicate; and it is then immediately attracted by the mug.

The reason why in this experiment the electrometer contracts no Electricity whilst suspended intirely within the cavity of the mug, is, because the Electricity of the mug acts upon the electrometer on all sides, and this has no opportunity of parting with its fluid, when the mug is electrified positively;

nor

nor of receiving any, when the mug is electrified negatively. But, as soon as any Conductor communicates with it, the electrometer becomes immediately possessed of the Electricity contrary to that of the mug; for if the mug be electrified positively, the fluid belonging to the electrometer will be repelled to that body, which communicates with it; and which, being out of the mug, cannot be affected by its Electricity; and if the mug is electrified negatively, it will attract the fluid of the electrometer, which actually receives an additional quantity of it from that conducting body, with which it communicates. The electrometer therefore, becoming always possessed of a contrary Electricity, must necessarily be attracted.

If, by raising the silk thread a little, part of the electrometer, *i. e.* of its linen threads, are lifted just above the mouth of the mug, the balls will be immediately attracted; for then, by the action of the Electricity of the mug, it will acquire a contrary Electricity by giving to, or receiving the electric fluid from, the air above the cavity of the mug.

It

It has been supposed by some, that the electrometer in the above experiment (or any other small insulated body), hanging in the cavity of an electrified vessel, or the like, is not attracted by the sides of the vessel, because the attraction of Electricity, being as the squares of the distances inversely, cannot affect the electrometer one way more than another; it being demonstrable, that, if to every point of a spherical concave surface, equal centripetal forces are directed, decreasing as the squares of the distances from those points, a small body situated any where within that surface, would remain there, without being attracted one way more than another *.

But to this it may be replied, that the demonstration of the above-mentioned proposition, if it is applicable to spherical, or cylindrical concave surfaces, cannot, however, be applied to every kind of irregular cavities, with which (if they exceed not a certain size) the above experiment succeeds as well, as with the cylindrical cavity of the mug.

* NEWTON'S Principia, book I. prop. LXX.

In short, in this experiment, when the mug is electrified positively, it is supposed,

I. That the superinduced fluid, taking place upon the external surface, occasions the contiguous air to deposit its fluid upon a subsequent quantity of air, and this overcharged air occasions a contiguous circle, or quantity of air, to deposit its fluid upon its subsequent or next adjacent circle, and so on. II. That none of the superinduced

fluid can exist upon the internal surface of the mug, and therefore insulated bodies, intirely suspended therein, can acquire no Electricity, because the internal air has no opportunity of parting with its own fluid, except a small quantity about the mouth of the mug, where, accordingly, a little Electricity is observable. When the mug is electrified negatively, then it is supposed,

I. That the deficiency of fluid in the mug is only on its external surface; for the air, contiguous to this surface, by acquiring an additional quantity of electric fluid from the next stratum of air, may become electrified positively. II. That the internal surface of the mug is not undercharged, because its contiguous air, being surrounded

by

by the mug, cannot become overcharged, by acquiring an additional quantity of fluid, except a small quantity towards the mouth of the mug, where, accordingly, a little Electricity is observable.

EXPERIMENT VI.

To distinguish the Quality of Electricity in electrified Bodies.

Before we proceed further, it is necessary that we should describe some practical method of distinguishing the quality of the Electricity in an electrified body, which is absolutely necessary for the right performance of the ensuing experiments. To do this, different methods may be followed, which however are all founded, either upon the electric attraction, and repulsion, or upon the different appearances of the electric light. To find out the quality of Electricity by the different appearances of its light, is a very convenient, and sure method; but the phenomena of attraction and repulsion, afford one much more general, and easy; for sometimes the quantity of Electricity to be observed is so very small,

small, that it will give no light, though it may be still capable of attracting or repelling.

The general method to prove whether the Electricity of a body, electrified either by excitation, or communication, is negative, or positive, is to bring it pretty near to an electrified electrometer D or C fig. 4, and observe whether the body attracts or repels it; for if the electrometer is electrified positively, and the electrified body repels it, then you may conclude that the body is also electrified positively; because bodies, possessed of the same kind of Electricity, repel each other; but if the body presented attracts the Electrometer, then it must be electrified negatively, because there is no electric attraction between bodies, unless they are differently electrified; and as the electrometer is known to be electrified positively, the body is consequently electrified negatively.

This may be also done by electrifying the electrometer negatively; but then the effects are just the contrary, *i. e.* the electrified

fied body, if negative, will repel the electrometer, and if positive, will attract it.

In this experiment, however, it must be observed, that, if the Electricity of the electrified body is much stronger than that of the electrometer, or the Electricity of the latter stronger than that of the former, and the electrified body be brought very near the electrometer, then they will attract one another, notwithstanding they are possessed of the same kind of Electricity. Suppose, for instance, that one of the electrometers C is positively electrified, so that its cork-balls may diverge about half an inch, and a glass tube strongly excited be brought near it; when this tube is a foot distant, or more, the electrometer will be a little repelled by it; but if the tube be brought nearer, the cork-balls, that before diverged half an inch, will now converge till they are in contact, and appear, as they actually are, unelectrified; because the action of the excited tube has repelled their superfluous fluid through the threads up to the remotest part of the electrometer. If the tube be presented still nearer, the balls will

will then be attracted by it, because the stronger Electricity of the tube repels not only their superinduced, but also their natural quantity of fluid up the threads, &c. and therefore the balls, becoming negatively electrified, must necessarily be attracted by the tube.

Upon this principle an electrometer may be electrified negatively by means of an electric positively excited; or, on the contrary, it may be electrified positively by an electric possessed of the negative Electricity. Take, for instance, a glass tube excited positively, and bring it within six or seven inches under the balls of one of the above-said electrometers; in which case the balls of the electrometer will diverge, because their natural quantity of electric fluid has been driven from them to the upper part of the threads by the action of the tube positively excited; so that the balls in reality diverge with negative Electricity. Now, in this state touch the upper part of the threads of the electrometer with your finger, which will take off some of the electric fluid natural to the electrometer;

P

after

after which remove the finger, and immediately after remove the glass tube, and the electrometer will remain electrified negatively, because the excited glass tube did not impart any electric fluid to the electrometer, but only disturbed the equilibrium of the natural quantity of electric fluid, which belonged to it, and part of which escaped through the finger that touched the electrometer, and which did consequently remain in a negative state.—After the like manner the electrometer may be electrified positively, by means of a body possessed of negative Electricity.

But should a more precise method than the above be required, to determine the quality of the Electricity of an electrified body, the following may be used:—First, electrify one of the electrometers C, placed upon the stand fig. 4, either positively, or negatively, at pleasure: touch it, for instance, with an excited glass tube, so that its balls may repel, and stand about two inches distant from one another; then touch the other electrometer C with the electrified body, that you desire to examine, so
that

that it may be possessed of the same degree of Electricity: Lastly, take either of the two electrometers by the top of the glass handle *a*, disengage it from the arm of the stand, and bring it near the other electrometer; if then the balls of one electrometer repel those of the other, you may conclude that they are possessed of the same kind of Electricity; but if they attract each other, you may conclude that they were electrified with contrary Electricities; and as you know the Electricity of that electrometer, which was first electrified, you will also know the Electricity of the other electrometer, *i. e.* of the electrified body, with which it was touched.

The above experiment may be also made with the single-thread electrometers; for if they are brought near to one another, when their feathers are electrified, they will, if possessed of the same Electricity, repel, or if possessed of contrary Electricities, attract each other.

EXPERIMENT VII.

The insulated metallic Rod.

Insulate in an horizontal position a metallic rod about two feet long, having blunt ends, and to one of its ends suspend an electrometer, like that represented fig. 3; then bring within three or four inches distance of its other end an excited glass tube. On the approach of the tube, the balls of the electrometer will open, and if you present towards them a body positively electrified, you will perceive, that they diverge with positive Electricity. If the tube is removed, the balls come together again, and no Electricity remains in them, or in the metallic rod. But if while the tube is near one end of the rod, and the balls diverge with positive Electricity, the other end of the rod, viz. that from which the electrometer hangs, be touched with some Conductor, the cork-balls will come immediately together, and they will remain so when the Conductor has been removed;

—remove

—remove now the excited glass tube, and the balls will immediately diverge with negative Electricity; which shows that the rod remains undercharged, *i. e.* electrified negatively.

The reason of this experiment is, that the repelling power of the excited tube, driving the fluid of one end of the rod to its other end, *i. e.* to that, with which the electrometer is connected, renders this end electrified positively; but in fact the tube communicates no Electricity to the rod, it only disturbs the equable diffusion of its fluid: in consequence of this, the electrometer, hanging to the overcharged end of the rod, must necessarily appear to be electrified positively; but when the tube is removed, then the electrometer appears again unelectrified: for the fluid, which had by the action of the tube been driven to one end of the rod, now retires to its former situation, and leaves the rod with the electrometer unelectrified.

In the second case, when the balls of the electrometer diverge with positive Electricity, if that end of the rod is touched with

some conductor, all its superfluous fluid, which is no other than that belonging to the opposite end of the rod, will be communicated to that body, with which the rod is touched, and therefore the electrometer remains unelectrified: but now in fact the rod has lost some of its natural quantity of fluid; for if the end of it, that is farthest from the excited tube, remains in its natural state, the other end is undercharged; consequently, when the tube is removed, the small quantity of fluid that remains in the rod will diffuse itself uniformly through it; but this quantity of fluid is less than that naturally inherent in the rod; the rod will therefore remain undercharged, and hence the balls of the electrometer diverge with negative Electricity.

This explanation is the same as that mentioned in the preceding experiment, *viz.* in the method of electrifying an electrometer negatively, with a body possessed of positive electricity, &c. ; but as this experiment is the basis, or key, of several others, I shall insist on it a little longer; and, to render its explanation more intelligible and clear,

clear, I shall make use of the following diagram :

A—————B.

Let the above-mentioned insulated rod be represented by the line A B. When this rod is in its natural state (in respect to Electricity) then the electric fluid belonging to it, is equally diffused throughout the rod. But when the excited tube is brought within three or four inches distance of one of the ends, for instance B, then the fluid, belonging to that end, will be driven to the end A ; which end therefore becomes overcharged, and the end B undercharged ; yet the rod has no more electric fluid now, than it had before ; and when the tube is removed to some distance from the rod, the superfluous fluid, repelled to the end A, returns to its former place, *i. e.* to the end B, and the equilibrium in the rod is restored. But if, when the fluid in the rod is repelled to the end A, this end be touched, the fluid repelled thither will immediately be conducted away by the body that touched it, and will leave the end A

of the rod in a natural state; but at the same time, the end B is undercharged; therefore, when the tube is removed, part of the natural fluid belonging to the end A, will go to the end B; and thus the whole rod will remain undercharged, *i. e.* negatively electrified.

If the above experiment be made with an electric negatively electrified (for instance, a rod of sealing-wax instead of the excited glass tube) then the apparent Electricities in the rod will be just the reverse of what they were before; for in this case, that end of the rod to which the electric has been presented, will be overcharged, and the opposite end undercharged; which opposite end, if touched in this state with some conducting substance, will acquire some electric fluid from that substance; and when, after that substance has been removed, the excited electric is also removed, the rod will remain overcharged.

In making this experiment, care must be taken that the end of the rod be very blunt, and that the electric be not very powerfully

powerfully excited; otherwise a spark may pass from this to the rod, which renders the experiment precarious.

EXPERIMENT VIII.

The two insulated metallic Rods.

Take two rods of metal, each about a foot long, furnished with knobs at both ends, and, either by silk lines, or by insulating stools, insulate them, so that they may stand horizontally in one direction, and at about half an inch distance from one another. To the middle of each of these rods hang an electrometer, like that represented fig. 3. This done, take an excited glass tube, and bring it to about three inches distance from the knob of one of the rods; on doing which, the electrometers of both rods will appear electrified: keep the tube in that situation for about two seconds, then remove it. The rods now will remain electrified, as appears by the electrometers; the first, *viz.* that to which the excited tube had been presented, remaining negative, and the other positive.

The

The reason of this phenomenon is, that when the tube was near the end of one of the rods, the action of its fluid repelling the fluid of that rod, caused it to pass in a spark to the other contiguous rod; on which account, when the tube was removed, the first rod, having lost some of its natural fluid, remained undercharged; and the other rod, acquiring the fluid lost by the former, became overcharged.

In this experiment, if, instead of the glass tube, an electric, negatively excited, be brought near the end of one rod, then that rod will be electrified positively, and the other negatively; for the action of this electric, producing just the contrary effect of the glass tube, instead of repelling the fluid of the first rod into the second, attracts that of the second into the first.

In this experiment the electric does not communicate any electricity of its own, but only disturbs the equilibrium between the fluid of the rods.

CHAP. VI.

Experiments on electric Light.

THE following experiments require to be made in the dark ; for although the electric light, in several circumstances, may be seen in the day-light, yet its appearance in this manner is very confused ; and, that the Electrician might form a better idea of its different appearances, it is absolutely necessary to perform such experiments in a darkened room.

EXPERIMENT I.

The Star and Pencil of electric Light.

When the electrical machine is in good order, and the prime Conductor is situated with the collector sufficiently near the glass cylinder (which situation I shall call hereafter its proper place) turn the winch, and you will see a lucid star at each of the points of the collector. This star is the
constant

constant appearance of the electric fluid that is entering a point. At the same time, you will see a strong light proceeding from the rubber, and spreading itself over the surface of the cylinder ; and, if the excitation of the cylinder is very powerful, dense streams of fire will proceed from the rubber, and, darting round almost half the circumference of the cylinder, will reach the points of the collector *.

If the chain of the rubber is taken off, and a pointed body (as for instance, the point of a needle or a pin) is presented to the back of the rubber, at the distance of about two inches, a lucid pencil of rays will appear to proceed from the point presented, and diverge towards the rubber.

* If the prime Conductor is removed, the dense streams of fire will go quite round the cylinder ; reaching from one side of the rubber to the other.—By observing on which side of the cylinder those streams are most copious, it may be easily determined which side of the rubber presses more or less upon the cylinder, or is better covered with amalgam, or, in short, which side is the most or least fit for the excitation of the glass.

This

This pencil is the constant appearance of the electric fluid issuing from a point; and in fact, it now comes out of the point, in order to supply the rubber, which is constantly exhausted by the cylinder in motion.

If another pointed body be presented to the prime conductor, it will appear illuminated with a star; but if a pointed wire, or other pointed conducting body, be connected with the prime Conductor, it will throw out a pencil of rays; for the prime Conductor being overcharged, the fluid departing from it must, agreeably to the law, form a pencil on that point from which it flies off, and a star on that point which it enters*.

F. BEC-

* It may be asked, why the electric fluid entering a point, causeth the appearance of a star; and when going out of the point, causeth the appearance of a brush of rays? In answer to this question, F. BECCARIA supposes, that the star is occasioned by the difficulty with which the electric fluid is extricated from the air, which is an electric. Suppose, for instance, that a pointed wire is presented to a body positively electrified, the electric fluid is first from that body communi-
cated

F. BECCARIA remarks, that if two equally sharp points are approached to a prime conductor, they will appear luminous at only half the distance at which one of them would have done.

From this experiment may be learned the method of distinguishing the quality of the Electricity of an electrified body, by the appearance of the electric light; for if a needle, or any other pointed body, be presented in the dark, with the point towards a body strongly electrified, it will appear illuminated with a star, when that body is electrified positively, and with a pencil or brush, when it is electrified negatively.

Here it is proper to remark, that if two points (one of which is connected with the cated to the air between it and the wire, and then the wire must extricate it from that air. The brush, he supposes to be occasioned by the force with which the electric fluid, going out of a point, runs through the contiguous air to that which is more remote from it; i. e. by dividing the contiguous air, and not by affixing itself to it.

prime

prime conductor, or the rubber) are opposed to one another, the appearance of light in both is pretty much the same. Mr. WILCKE remarks, that if a point not electrified, is opposed to another point electrified positively, the cones of light, which otherwise would appear upon them, disappear; but that if a positive cone be opposed to a negative cone, they both preserve their own characteristic properties*.

EXPERIMENT II.

Drawing Sparks.

Let the prime Conductor be situated in its proper place, and electrify it by working the machine; then bring a metallic rod with a round knob at each end, or the knuckle of a finger, within a proper distance of the prime Conductor, and a spark will be seen between that and the knuckle, or knobbed wire. The longer and stronger

* WILCKE, p. 140.—See BECCARIA's Art. Elect. § 941, and following.

spark is drawn from that end of the prime Conductor which is farthest from the cylinder, or rather from the end of the knobbed rod I B, fixed at its end B, fig. 2 *.

This spark (which has the same appearance, whether drawn from a prime Conductor positively, or negatively electrified) appears like a long line † of fire, reaching from the Conductor to the opposed body; and often (particularly when the spark is long, and different conducting substances are near the line of its direction) it will have the appearance of being bended to sharp angles in different places, exactly resembling a flash of lightning. Notwithstanding, however, this extended appearance, which is imputed to the quick passage of the luminous matter, the electric

* The reason of this, I think, is, because that end of the prime conductor is less influenced by the atmosphere of the excited cylinder.

† It often darts brushes of light sideways, in every direction.

fluid passing from one body to another in a spark, is reasonably thought to proceed in a separate, and nearly globular body.

The direction of the spark often deceives the most experienced Electrician, it seeming sometimes to proceed from one place, and at other times, under the same circumstances, to proceed from the opposite. When the prime Conductor is electrified positively, the spark must certainly proceed from it, and go to the body presented; and when the prime Conductor is electrified negatively, the spark must proceed from the body presented, and go to the Conductor. This, however, we learn by reasoning from other experiments; for the real direction of the spark in the above experiment, is much more rapid in its motion than to admit its form, much less its direction, to be perceived by our eyes. With Mr. NAIRNE'S machine, which is very powerful, it is observable, first, that the sparks from the negative conductor are more pungent than those from the positive; and secondly, which may be the cause of the preceding effect, that when a blunt body is

Q

presented

presented to the negative conductor, the spark appears branched towards the Conductor, and concentrated in one stock towards the body; but with the positive conductor the appearance of the spark is just the reverse.

A, longer spark may be drawn from a larger than from a smaller Conductor, except when the Conductor exceeds a certain size. The Conductor, which, when put before an ordinary electrical machine, will give sparks about equal in length to the diameter of the glass cylinder of the machine, is the largest that can be used to advantage; for a longer spark cannot be obtained, except in some particular cases, *viz.* when some particles of dust, or other extraneous matter, happen to be interposed between the Conductor and the brass ball, or other substance, that is opposed to it, &c. as will appear from the following reasoning:—The circumference of the glass cylinder is nearly equal to three times its diameter. The rubber, with its piece of silk, &c. may occupy about one third part of the said circumference, and consequently the collector of the Conductor, when put in the middle of the remaining

maining surface, at most cannot be farther from the rubber than the length of one diameter of the cylinder; viz. one third part of the circumference; therefore it is plain that if the cylinder could give a spark longer than the diameter of the cylinder, the spark would be darted to the rubber, rather than to any other body placed farther off from the Conductor.— When the rubber of the machine is made to communicate with the earth, by means of imperfect conductors, as a piece of wood, &c. then the Conductor will give a spark generally longer than when perfect conductors are employed for the said communication. In this case it may happen, that a spark some small matter longer than the diameter of the cylinder, might be obtained.

EXPERIMENT III.

The electric Light flashing between two metallic Plates.

Let two persons, one standing upon an insulated stool, and communicating with the prime Conductor, and another standing upon the floor, each hold in one of his

Q 2 hands

hands a metal plate, in such a manner, that the plates may stand back to back in a parallel situation, and about two inches asunder. Let the winch of the machine be turned, and you will see the flashes of light between the two plates so dense and frequent, that you may easily distinguish any thing in the room. By this experiment, the electric light is exhibited in a very copious and beautiful manner, and it bears a striking resemblance to lightning.

EXPERIMENT IV.

To fire inflammable Spirits.

The power of the electric spark to set fire to inflammable spirits, may be exhibited by several different methods; but more easily thus:— Hang to the prime Conductor a short rod, having a small knob at its end, then pour some spirit of wine, a little warmed, into a metal spoon*; hold the spoon by the handle, and place

* The readiest way to warm the spirits for this experiment, is to set it on fire with a candle when it is in the

place it in such manner, that the small knob on the rod may be about one inch above the surface of the spirit. In this situation, if, by turning the winch, a spark be made to come from the knob, it will set the spirit on fire.

This experiment happens in the very same manner, whether the Conductor is electrified positively or negatively, *i. e.* whether the spark be made to come from the Conductor, or from the spoon; it being only in consequence of the rapid motion of the spark that the spirits are kindled,

It will be perhaps scarce necessary to remark, that the more inflammable the spirits are, the more proper they will be for this experiment, as a smaller spark will be sufficient to inflame them; therefore rectified spirit of wine is better than common proof spirit, and æther better than either.

the spoon, and, after it has burned for about two or three seconds, to blow it out with your breath. In this state it will be found very ready to take fire, even by a small spark.

Q 3

This

This experiment may be varied different ways, and may be rendered very agreeable to a company of spectators. A person, for instance, standing upon an electric stool, and communicating with the prime Conductor, may hold the spoon with the spirits in his hand, and another person, standing upon the floor, may set the spirits on fire, by bringing his finger within a small distance of it. Instead of his finger, he may fire the spirits with a piece of ice; when the experiment will seem much more surprizing. If the spoon is held by the person standing upon the floor, and the insulated person brings some conducting substance over the surface of the spirit, the experiment succeeds as well.

“ Mr. WINCKLER says, that oil, pitch,
 “ and sealing-wax, might be lighted by
 “ electric sparks, provided those substances
 “ were first heated to a degree next to
 “ kindling. To these it must be added,
 “ that Mr. GRALATH fired the smoke of
 “ a candle just blown out, and lighted it
 “ again; and that Mr. BOZE fired gun-
 “ powder,

" powder, melting it in a spoon, and first
 " the vapour that rose from it."



EXPERIMENT V.

*The artificial Bolonian Stone illuminated
 by the electric Light.*

The most curious experiment to shew the penetrability of the electric light, is made with the real, or with the artificial Bolonian stone, which is procured more easily, and was invented by the late Mr. J. CANTON. This phosphorus is a calcareous substance, generally used in the form of a powder, which has the property of appearing lucid, when brought into the dark after having been exposed to the light †.

Take

* PRIESTLEY's Hist. of Elect. period VII.

† The method of making this phosphorus is as follows: " Calcine some common oyster-shells" (if they are old, and half calcined by time, such as are commonly found upon the sea-shore, they are, as Mr. W. CANTON observes, so much the better) " by keeping
 " them in a good coal-fire for half an hour; let the

Q 4

" purest

Take some of this powder, and, by means of spirit of wine, or æther, stick it all over the inside of a clear glass phial, and stop it with a glass stopper, or a cork and sealing-wax. If this phial be kept in a darkened room (which for this experiment must be very dark) it will give no light; but let two or three strong sparks be drawn from the prime Conductor, when the phial is kept at about two inches distance from

“ purest part of the calx be pulverized, and sifted ;
 “ mix with three parts of this powder one part of the
 “ flowers of sulphur ; let this mixture be rammed into
 “ a crucible of about an inch and a half in depth, till it
 “ be almost full ; and let it be placed in the middle of
 “ the fire, where it must be kept red-hot for one hour
 “ at least, and then set it by to cool : when cold, turn
 “ it out of the crucible, and cutting or breaking it to
 “ pieces, scrape off, upon trial, the brightest parts ;
 “ which, if good phosphorus, will be a white powder,
 “ and may be preserved by keeping it in a dry phial
 “ with a ground stopple.”

If this phosphorus, whether in the phial or not, be kept in the dark, it will give no light, but if exposed to the light, either of the day, or of any thing else, and afterwards brought into a dark place, it will then appear lucid for a considerable time. For farther properties of this phosphorus, see the Phil. Transf. Vol. LVIII.

the

the sparks, so that it may be exposed to that light, and this phial will receive the light, and afterwards will appear illuminated for a considerable time.

This powder may be stuck upon a board by means of the white of an egg, so as to represent figures of planets, letters, or any thing else, at the pleasure of the operator, and these figures may be illuminated in the dark, in the same manner as the above-described phial.

A beautiful method to express geometrical figures with the above phosphorus, is to bend small glass tubes, of about the tenth part of an inch diameter, in the shape of the figure desired, and then to fill them with the phosphorus powder. These may be illuminated in the manner described, and they are not so subject to be spoiled, as the figures represented upon the board frequently are.

The best method of illuminating this phosphorus, and was that Mr. W. CANTON generally used, is to discharge a small electric jar near it.

Paper,

Paper, after being made dry and rather hot, marble, oyster-shells, and most calcareous substances, especially when burned to lime, have the property of being illuminated by the light given by the discharge of a jar, though not so much as the above-mentioned phosphorus.

EXPERIMENT VI.

The luminous Conductor.

Fig. 6. Plate I. represents a prime Conductor invented by Mr. HENLY, which shews clearly the direction of the electric fluid passing through it, from whence it is called *the luminous Conductor* *. The middle part EF of this Conductor is a glass tube about eighteen inches long, and three or four inches in diameter. To both ends of this tube the hollow brass pieces FD, BE, are cemented air-tight, one of which has a point C, by which it receives the

* An instrument much like this Conductor was some years ago contrived by Dr. WATSON, with which he made several original experiments upon the electric

electric

electric fluid, when set near the excited cylinder of the electrical machine, and the other has a knobbed wire G, from which a strong spark may be drawn; and from each of the pieces F D, B E, a knobbed wire proceeds, within the cavity of the glass tube. The brass piece F D, or B E, is composed of two parts. *i. e.* a cap F cemented to the glass tube, and having a hole with a valve, by which the cavity of the glass tube may be exhausted of air; and the ball D, which is screwed upon the cap F. The supporters of this instrument are two glass pillars fastened in the bottom board H, like the prime Conductor represented fig. 2. When the glass tube of this Conductor is exhausted of air by means of an air pump, and the brass ball is screwed on, as represented in the figure, then it is fit for use, and may serve for a prime Conductor to an electrical machine.

If the point C of this Conductor is set near the excited cylinder of the machine, it will appear illuminated with a star; at the same time the glass tube will appear all illuminated with a weak light; but from the

the knobbed wire, that proceeds within the glass from the piece F D, a lucid pencil will issue out, and the opposite knob will appear illuminated with a star or round body of light, which, as well as the pencil of rays, is very clear, and discernible among the other light, that occupies the greatest part of the cavity of the tube.

If the point C, instead of being presented to the cylinder, be connected with the rubber of the machine, the appearance of light within the tube will be reversed; the knob which communicates with the piece F D appearing illuminated with a star, and the opposite with a pencil of rays; because in this case the direction of the electric fluid is just the contrary of what it was before; it then going from D to B, and now coming from B and going to D.

If the wires within the tube E F, instead of being furnished with knobs, be pointed, the appearance of light is the same, but it seems not so strong in this, as in the other case.

EXPE-

EXPERIMENT VII.

The conducting Glass Tube.

Take a glass tube of about two inches diameter, and about two feet long; fix to one of its ends a brass cap, and to the other a stop-cock, or a valve; then by means of an air-pump exhaust it of air. If this tube be held by one end, and its other end be brought near the electrified prime Conductor, it will appear to be full of light, whenever a spark is taken by it from the prime Conductor; and much more so, if an electric jar be discharged through it.

This experiment may also be made with the receiver of an air-pump.—Take, for instance, a tall receiver, clean and dry, and through a hole at its top insert a wire, which must be cemented air-tight. The end of the wire, that is within the tube, must be pointed, but not very sharp; and the other end must be furnished with a knob. Put this receiver upon the plate of
the

the air-pump, and exhaust it. If now the knob of the wire at the top of the receiver be touched with the prime Conductor *, every spark will pass through the receiver in a dense and large body of light, from the wire to the plate of the air-pump.

It must be observed, that when the air is very much rarefied, the electric light in it is less dense, though more diffused, and contrarywise.

EXPERIMENT VIII.

The Aurora Borealis.

Take a phial nearly of the shape and size of a Florence flask; fix a stop-cock or a valve to its neck, and exhaust it of air as much as it is possible with a good air-pump. If this glass is rubbed in the common manner used to excite electrics, it will

* When any thing is to be touched with the prime Conductor, that is not very portable, as the air-pump above mentioned, the communication between the former and the latter may be made by means of a rod furnished with an electric handle, or the like.

appear

appear luminous within, being full of a flashing light, which plainly resembles the aurora borealis, or northern light. This phial may also be made luminous by holding it by either end, and bringing the other end to the prime Conductor; in this case all the cavity of the glass will instantly appear full of flashing light, which remains in it for a considerable time after it has been removed from the prime Conductor.

Instead of the above-described glass vessel, a glass tube, exhausted of air and hermetically sealed, may be used, and perhaps with better advantage. The most remarkable circumstance of this experiment is, that if the phial or tube, after it has been removed from the prime Conductor (and even several hours after its flashing light hath ceased to appear) be grasped with the hand, strong flashes of light will immediately appear within the glass, which often reach from one of its ends to the other.

The causes on which this experiment depends are two; first, the conducting nature of the vacuum; and, second, the charging

ing of the glass: for when one side of the glass phial is touched with the prime Conductor, the electric fluid, communicated to the outside surface of one side of the phial, causeth the natural fluid belonging to the inside surface to depart from its place, and go to the opposite side of the phial; and this fluid, passing through the vacuum, causes the light within the phial, which light is more or less subdivided, according as the vacuum is less or more perfect. Now, that part of the phial, which has touched the prime Conductor, is actually charged; for its outside surface has acquired an additional quantity of electric fluid, and the inside surface has lost part of its own; but as the outside of the phial has no coating, therefore, when it is removed from the prime Conductor, and is not grasped with the hand, or other Conductor, the charged part of the glass can be discharged only gradually; that is, whilst its outside surface is communicating its superfluous fluid to the contiguous air, the inside surface acquires the electric fluid from the other end of the phial, which fluid passing through the vacuum, causes that flashing, which

which is observed for so considerable a time. If the phial is grasped with the hand, its discharge is accelerated, hence the flashes within the phial appear more dense and copious; yet it cannot be discharged all at once by this operation, because the hand cannot touch every part of the glass at once.

EXPERIMENT IX.

The visible electric Atmosphere.

GI fig. 2. Plate II. represents the receiver with the plate of an air-pump. In the middle of the plate IF, a short rod is fixed, having at its top a metal ball B nicely polished, whose diameter is nearly two inches. From the top of the receiver, another rod AD with a like ball A proceeds, and is cemented air-tight in the neck C; the distance of the balls from one another being about four inches, or rather more. If, when the receiver is exhausted of air, the ball A be electrified positively, by touching the top D of the rod AD with the prime Conductor or an excited glass tube,

R

tube,

tube, a lucid atmosphere appears about it, which, although it consists of a feeble light, is yet very conspicuous, and very well defined; at the same time the ball B has not the least light. This atmosphere does not exist all round the ball A, but reaches from about the middle of it, to a small distance beyond that side of its surface, which is towards the opposite ball B. If the rod with the ball A be electrified negatively, then a lucid atmosphere, like the above-described, will appear upon the ball B, reaching from its middle to a small distance beyond that side of it, that is towards the ball A; at the same time the negatively electrified ball A remains without any light.

The Operator in this experiment, must be careful not to electrify the ball A too much, for then the electric fluid will pass in a spark from one ball to the other, and the experiment will not have the desired effect. A little practice, however, will render the operation very easy and familiar.

For this and similar experiments I must recommend to the ingenious the new patent
5 air-pump,

air-pump, lately invented by Mr. HAAS, and now made by Mr. HURTER, in Great Marlborough Street, London, who is the proprietor of the patent. This machine, besides its exhausting incomparably more than any other air-pump, has several other properties, which render it the completest instrument of the kind. For a description of this air-pump, see the Phil. Trans. vol. LXXIII.

By this elegant experiment, which is of the celebrated F. BECCARIA, we have an ocular demonstration of the theory of a single electric fluid; we see that Electricity consists of one uniform homogeneous fluid, and not two, *viz.* the vitreous, and resinous, as some have supposed; for if the positive and negative Electricity were two distinct fluids, attractive of one another, there should, in the above experiment, always appear two atmospheres, *i. e.* one about the ball A, and another about the ball B; for when the ball A is overcharged with either fluid, it should shew that superfluous fluid on its surface, and this fluid should attract towards the ball A, an atmosphere of the contrary fluid from the

R 2

ball

ball B. But this, as we observed before, is not the case ; for the appearance of the lucid atmosphere is always on one ball, namely, that which is overcharged with the electric fluid ; thus, when the ball A is electrified positively, the superfluous fluid is visible on that part of it which is nearest to the ball B, because B, being in a contrary state of Electricity, endeavours to attract it ; but, when the ball A is electrified negatively, it will attract the fluid proper to the ball B, which fluid on that account appears upon the surface of B, just in the act of leaping to the ball A.

In order to remove an error, that has been adopted by several writers on Electricity, it will be not amiss in this chapter to mention, that the electric light has all the prismatic colours, as well as the light of the sun. This may be easily experienced by viewing an electric spark through a glass prism *.

* See Dr. PRIESTLEY's History of Electricity, part VIII. sec. XIII. n. XII.

CHAP. VII.

Experiments with the Leyden Phial.

EXPERIMENT I.

Of charging, and discharging a Phial in general.

TAKE a coated jar, as DE, fig. 2, Plate I, and place it upon the table near the prime Conductor, so that the knob of its wire, and that only, may be in contact with it: fix the quadrant electrometer E, fig. 2, upon the prime Conductor, and then turn the winch of the machine. You will observe, that as the jar is charging, the index of the electrometer will rise gradually as far as 90° , or thereabouts, and then rest: when this happens, you may conclude, that the jar has received its full charge. If now you take a discharging rod, and, holding it by the glass handle, apply first one of its knobs to the outside coating of the jar, and then bring the other knob near the knob of the wire of the jar,

or near the prime Conductor, that communicates with it, you will hear a report, and see very vivid sparks between the discharging rod and the conducting substances, communicating with the sides of the jar. This operation discharges the jar. If, instead of using the discharging rod, you touch the outside of the jar with one hand, and bring the other hand near the wire of the jar, the same spark and report will follow, but now you will feel a shock, which affects your wrists, elbows, and, if strong, your breast also *. If a number of persons join hands, and the first of them touches the outside of the jar, and the last touches the wire communicating with the inside, they will all feel the shock, and precisely at the same perceivable time. This shock bearing no resemblance to any sensation otherwise felt, cannot consequently be described; and in order that a person may form a just idea of it, he must absolutely feel it.

If many persons lay hold of a metal plate that communicates with the outside of a

* A shock may be given to any single part of the body, if that part only be brought into the circuit.

charged

charged jar, and all together do also hold a metal rod with which the discharge is made, they will all feel the shock; which shews that the discharge has been made through several circuits at once.

The reason of the charging of the phial or jar in this experiment is, that when a superfluous quantity of electric fluid is forced upon the inside surface of the glass, it causeth an equal quantity of fluid, naturally inherent in the glass, to depart from the opposite surface, in consequence of the repulsion natural to the particles of the electric fluid, which repulsion is exerted even through the glass; one side therefore of the glass remains overcharged, and the other undercharged; as soon, therefore, as the communication between the two sides of the jar is compleated, the superfluous fluid on one side of the glass flies violently to the other side, and the rapidity of its motion occasions the spark, the report, &c.

If the coated jar be held by the wire communicating with its inside, and the outside coating be presented to the prime

Conductor, it will be charged as readily as in the other method, but with this difference, that in this case the outside will be positive, and the inside negative.

We have supposed above, that the prime Conductor was electrified positively; but if the experiment be repeated when the Conductor, by being connected with the rubber of the machine, is electrified negatively, the jar would in the same manner be charged; except that in this case the side that touches the prime Conductor would be electrified negatively, and the opposite side positively.

EXPERIMENT II.

To shew that an insulated Jar cannot be charged.

Set a coated jar upon an electric stool; connect its wire, or its outside coating with the prime Conductor, and turn the winch of the machine. You will then observe, that the index of the quadrant electrometer, placed upon the prime Conductor, soon rises

rises to 90°, seemingly shewing that the jar is charged. Then remove the electric stool with the jar from the prime Conductor, and either with a discharging rod, or with your hands, endeavour to discharge the jar, and you will find, that it is not charged; for no remarkable spark, no shock, nor any other phenomenon of charged glass, will appear.

The reason why in this experiment the inside of the jar could acquire no additional electric fluid, and therefore the jar could acquire no charge, is because the outside could not at the same time part with its own fluid, its communication with the earth being cut off by the electric stool. But repeat this experiment with only this variation, that, by means of a chain or otherwise, the outside of the jar be made to communicate with the table, and you will then find, that the jar will be charged; for in this case the fluid, naturally inherent in the outer surface of the jar, can readily be repelled through the chain, &c. into the table.

Strictly

Strictly speaking, the jar in this experiment will acquire a very slight charge, because some of the electric fluid belonging to its outside will be imparted to the air, &c.

If a jar be insulated, and one side of it, instead of being connected with the earth, be connected with the insulated rubber, whilst the other side communicates with the prime Conductor, the jar will be also charged, and perhaps in a more expeditious manner; for whilst the rubber exhausts one side, the other side is supplied by the prime Conductor. In this manner it is shown, that the jar is charged with its own fluid, *i. e.* the natural electric fluid of one of its sides is, by the action of the machine, thrown on the other side.

EXPERIMENT III.

The preceding Experiment diversified.

To make the above experiment in a clearer, and more satisfactory manner, place the jar upon the stool as before, and
with

with its wire not in contact, but at about half an inch distance from the prime Conductor; hold the knob of another wire at such a distance from the outside coating of the jar, as the knob of the jar is from the prime Conductor, then let the winch of the machine be turned, and you will observe, that whenever a spark comes from the prime Conductor to the wire of the jar, another spark passes from the outside coating of the jar to the knob of the wire presented towards it; which shews, that as a quantity of electric fluid is entering the inside of the jar, an equal quantity of it is leaving the outside. In this manner the jar becomes charged.

If instead of the knobbed wire, a pointed one be presented to the outside of the jar, it will appear illuminated with a star; and if instead of presenting any wire to the jar, a pointed wire be connected with its coating, it will appear illuminated with a brush of rays (*i. e.* by throwing the electric fluid into the air), which will last as long as the jar is charging.

If

If the knob of another jar be presented to the outside coating of the insulated jar in the above experiment, it will also be charged; for the fluid, going out of the outside coating of the first jar, *i. e.* that standing upon the stool, will go in the inside of the other jar, and cause the fluid, inherent to the outside of that jar, to depart from its place*.

EXPERIMENT IV.

To shew that the Charge of a Jar, or Glass in general, does not reside in the Coating.

Take a naked phial, and for a coating on the outside stick a piece of tin-foil, with a little tallow or bees-wax, so that it can just adhere to the glass; and for an inside

* It is easy to understand from this experiment, how several phials may be connected together, so that they may be charged all at once, with nearly the same trouble as one is charged. It must, however, be observed, that when several jars are so connected, that the inside of one communicates with the outside of another, &c. they cannot be charged so high, nor so easily, as otherwise; the difficulty increasing nearly in proportion to the number of jars.

coating

coating use small leaden shot, or quicksilver; lastly, insert through its neck a knobbed wire communicating with the shot or quicksilver.—This done, hold the phial thus coated by its outside coating, and charge it, by presenting its knobbed wire to the prime Conductor. When it is charged, turn it upside down, and let its wire and quicksilver, or shot, fall in a glass receiver; then remove its outside coating also. In this operation the phial does not lose its charge, and if you examine the quicksilver or shot, you will find that it contains no more Electricity than any other like conducting insulated body, which has been in contact with the prime Conductor, would contain. Replace the outside coating again upon the phial, pour the shot or quicksilver again into it, or any other conducting substance, then touch with one hand the outside coating, and with the other, by introducing a finger or a wire, touch the inside non-electric, and you will feel a shock; which will convince you, that the glass has lost very little of its charge by the operation above mentioned.

The

The same experiment may be more conveniently made by laying a pane of glass upon a metal plate, and covering an equal part of the upper surface with tin-foil, having a silk thread fastened to one of its sides, by which it may be easily taken off, when the glass is charged, and as easily replaced, when required.

EXPERIMENT V.

To prove that the electric Fluid does not expel the Air contained in a Phial.

Through a hole made in the cork that stops a coated phial, introduce a small glass tube open at both ends, and of about one thirtieth part of an inch in diameter; bend that part of the tube, that is out of the phial, in an horizontal situation, and with bees-wax fasten the cork so, that no air can get in or out of the phial, except it passes through the glass tube; lastly, put a small drop of red wine, or ink, in the horizontal part of the tube, so that it may be easily moved through it, by the least rarefaction or condensation of the air within the phial.

If

If this phial thus furnished be charged, by connecting the prime Conductor with its wire, the drop of liquor in the glass tube will not be stirred from its situation; which shews that the electric fluid, immitted into the phial, does not exclude any of the air that the phial contains. If the phial be discharged, the drop of liquor in the tube will be often pushed a little out of its place, and afterwards return to its former situation; which shews, that on making the discharge, the air within the phial was a little displaced, or rarefied. This, however, is to be imputed to some spark, that generally happens within the cavity of the phial, on account that the wire is not in perfect contact with the inside coating*.

* Having repeated this experiment with a small phial, whose charging-piece (as we may call it) was a production of the inside coating, (which was of one piece of tin-foil, stuck to the glass with bees-wax, in consequence of which no spark could happen within the phial) I found that the drop of liquor in the glass tube was not stirred, either in charging or discharging the phial.

EXPERIMENT

EXPERIMENT VI.

The Course of the electric Fluid in the Discharge rendered visible by the Star and Pencil.

When a jar is charged, take a discharging rod having its ends pointed, *i. e.* the discharging rod represented in fig. 10. Plate I. without its knobs, and keep it as represented, fig. 11. that is, in such a situation, that one of its points C may be at about one inch distance from the knob A, and the other point B at an equal distance from the outside coating of the jar; by these means the jar will be discharged silently; and if its inside be electrified positively, you will see, that the point C of the discharging rod is illuminated with a star, and the point B with a pencil; because, in this case, the electric fluid, going from the inside to the outside of the jar, enters the point C, and issues from the point B. But if the jar is electrified negatively on the inside, and consequently positive

tive on the outside, then the pencil of rays will appear upon the point C, and the star upon the point B; for in this case the electric fluid passes from the outside to the inside of the jar.

N. B. This experiment, as well as any other, in which the electric light is to be observed, requires to be made in the dark.

EXPERIMENT VII.

The Course of the electric Fluid in the Discharge shewn by the Flame of a Wax-taper.

Remove the circular piece of wood E from the universal discharger, represented fig. 5. Plate I. Fix the wires D B, D C, so that their knobs D D may be about two inches distant from one another; and upon the socket F fix a piece of wax-taper lighted, so that its flame may be just in the middle, between the knobs D D. Having disposed the apparatus in this manner, if you connect, by means of a chain or otherwise, the outside of a charged jar with one

S of

of the wires C, and bring the knob of the jar to the other wire C, you will observe, that on making the discharge, which must pass between the knobs D D, the flame of the wax-taper is always driven in the direction of the electric fluid; that is, it will be blown upon the knob of that wire, which communicates with that side of the jar which is negatively electrified.

In this experiment, the jar must have an exceeding small charge, just sufficient to pass through the interval in the circuit; which experience will presently determine; otherwise the experiment will not succeed, or be perhaps rendered equivocal*.

* If it be asked, Why this experiment does not succeed with a great explosion as well as with a very small one? the answer is, that when a jar highly charged, is brought near one of the wires of the universal discharger, it creates an atmosphere about the knob of the said wire, which atmosphere disturbs the flame of the wax-taper, before the actual discharge: besides, the electric fluid in a great explosion, by its elastic nature, passes through the flame of the wax-taper too swiftly to communicate to it any visible motion; in the same manner as a bullet, discharged from a pistol against an open door, makes a hole through the door without shutting it.

EXPERIMENT

EXPERIMENT VIII.

The Course of the electric Fluid in the Discharge, rendered conspicuous by the Motion communicated to a Pith Ball.

Bend a card, length-ways, over a round ruler, so as to form a channel, or semicircular groove * : lay this card upon the circular board E of the universal discharger, represented fig. 5. of Plate I. and in the middle of it put a pith-ball of about half an inch diameter ; then at equal distances, about half or three quarters of an inch from the pith-ball, lay the two brass knobs D D. The card being perfectly dry, and rather hot, if you connect, by means of a chain or otherwise, the outside of a charged jar with one of the wires C, and bring the knob of

* Instead of the card, a piece of baked wood may be cut in that shape, and painted over with lamp-black and oil ; which will answer better than the card, it being much more steady, and not so liable to attract moisture.

the jar to the other wire C, you will observe, that on making the discharge, which must pass between the knobs D D, and over the card, &c. the pith-ball is always driven in the direction of the electric fluid; *i. e.* it is pushed towards that knob which communicates with the negative side of the jar.

It must be observed, that in this experiment the charge of the jar must be just sufficient to pass through the interval in the circuit; the card, or piece of baked wood, must be very dry and clean; and, in short, the disposition of the apparatus, and the performance of this curious experiment, require a degree of nicety that can only be obtained by practice. Without great precaution, it sometimes fails; but when the operator has once got it to succeed, and follows exactly the same method of operating, he may be sure that the event of the experiment will be constantly as above described.

EXPERIMENT



EXPERIMENT IX.

The Leyden Vacuum.

Fig. 8 and 9. of Plate I. represent a small phial coated on the outside about three inches up the sides with tin-foil; at the top of the neck of this phial, a brass cap is cemented, having a hole with a valve, and from the cap a wire proceeds a few inches within the phial, terminating in a blunt point. When this phial is exhausted of air, a brass ball is screwed upon the brass cap, so as to defend the valve, and prevent any air from getting into the exhausted glass *. This phial exhibits clearly the direction of the electric fluid, both in charging and discharging; for if it be held by its bottom, and its brass knob be presented to the prime Conductor positively electrified, you will see that the

* The inside of this phial requires no coating, because, as the electric fluid pervades vacuum, it can pass freely from the wire to the surface of the exhausted glass, without the help of a non-electric coating.

electric fluid causeth the pencil of rays to proceed from the wire within the phial, as represented fig. 9. and if it is discharged, a star will appear in the place of the pencil, as represented in fig. 8. But if the phial is held by the brass cap, and its bottom be touched with the prime Conductor, then the point of the wire, on its inside, will appear illuminated with a star when charging, and with a pencil when discharging. If it be presented to a prime Conductor electrified negatively, all these appearances, both in charging and discharging, will be reversed.

This experiment of the Leyden Vacuum, together with the two preceding ones, namely the seventh and eighth of this chapter, are inventions of Mr, HENLY,

EXPERIMENT X.

*To pierce a Card, and other Substances, with
the electric Explosion.*

Take a card, a quire of paper, or the cover of a book, and keep it close to the outside coating of a charged jar; put one knob of the discharging rod upon the card, quire of paper &c. so that between the knob and coating of the jar, the thickness of that card, or quire of paper, only is interposed; lastly, by bringing the other knob of the discharging rod near the knob of the jar, make the discharge; and the electric matter rushing through the circuit, from the positive to the negative surface of the jar, will pierce a hole (or perhaps several) quite through the card, or quire of paper *. This hole has a bur raised on

* The hole, or holes, are larger or smaller, according as the card, &c. is more damp or more dry. It is remarkable, that if the nostrils are presented to it, they will be affected with a sulphureous, or rather a phosphoreal smell, just like that produced by an excited Electric,

each side, except the card, &c. be pressed hard between the discharging rod and the jar; which shews that the hole is not made in the direction of the passage of the fluid, but in every direction from the center of the resisting body.

If this experiment be made with two cards instead of one, which however must be kept very little distant from one another *, each of the cards, after the explosion, will be found pierced with one or more holes, and each hole will have burrs on both surfaces of each card.

If, instead of paper, a very thin plate of glass, rosin, sealing-wax, or the like, be interposed between the knob of the discharging rod, and the outside coating of the jar, on making the discharge, this will be broken in several pieces,

Small insects may also be killed in this manner; they may be held between the

* This may be easily effected by bending one of the cards a little.

outside coating of the jar, and the knob of the discharging rod, like the above-mentioned card; and a shock of a common phial sent through them, will instantly deprive them of life, if they are pretty small; but if larger, they will be affected in such a manner, as to appear quite dead on first receiving the stroke, but will, after some time, recover: this, however, depends on the quantity of the charge sent through them.

If a shock is sent through a lump of white sugar, strong enough to break the sugar, the shock will illuminate every piece of it, so as to afford a beautiful experiment in the dark.—The sugar will give light for about a minute afterwards.

EXPERIMENT XI.

To shew the Effect of the Shock sent over the Surface of a Card or other Substances.

Put the extremities of two wires upon the surface of a card, or other body of an electric nature, so that they may be in
one

one direction, and about one inch distance from one another; then, by connecting one of the wires with the outside of a charged jar, and the other wire with the knob of the jar, the shock will be made to pass over the card or other body.

If the card be made very dry, the lucid track between the wires will be visible upon the card for a considerable time after the explosion. If a piece of common writing-paper be used instead of the card, it will be torn by the explosion into very small bits,

If, instead of the card, the explosion is sent over the surface of a piece of glass, this will be marked with an indelible track, which generally reaches from the extremity of one of the wires to the extremity of the other. In this manner the piece of glass is very seldom broken by the explosion. But Mr. HENLY has discovered a very remarkable method to increase the effect of the explosion upon the glass; which is by pressing with weights that part of the glass, which lies between the two wires,

wires, (*i. e.* that part, over which the shock is to pass). He puts first a thick piece of ivory upon the glass, and places upon that ivory a weight at pleasure, from one quarter of an ounce to six pounds: The glass in this manner is generally broken by the explosion into innumerable fragments, and some of it is absolutely reduced into an impalpable powder. If the glass is very thick, and resists the force of the explosion, so as not to be broken by it, it will be found marked with the most lively prismatic colours, which are occasioned by very thin laminæ of the glass, in part separated from it by the shock. The weight laid upon the glass is always shook by the explosion, and sometimes it is thrown quite off from the ivory *. This experiment may be most conveniently made with the universal discharger. Fig. 5. of Plate I.

* If small representations of houses, &c. be laid upon a board, placed on the piece of ivory; that, being shook by the explosion, will give a very natural idea of an earthquake.

EXPERIMENT

EXPERIMENT XII.

To shew the Direction of the electric Fluid in the Discharge, by causing the Shock to go over the Surface of a Card.

Dispose the apparatus in the manner described in the preceding experiment, but with this difference, that instead of laying the extremities of both wires upon the same side of the card, one of them be placed under the card; then send a shock through the said wires, as in the preceding experiment, and you will observe, that the electric fluid will run over that surface of the card, upon which lies the extremity of that wire, which is connected with the positive side of the jar; and in order to pass to the extremity of the other wire, it will break a hole through the card just over the extremity of that wire, which is connected with the negative side of the jar.

This excellent experiment, which shows the direction of the electric fluid in the discharge of a jar, is a discovery of Mr. LULLIN, of Geneva.

N. B.

N. B. With very large jars, this experiment has been observed to pierce several holes, and in such manner as to render the result not satisfactory.

EXPERIMENT XIII.

To swell the Clay, and break small Tubes with the electric Explosion.

Roll up a piece of soft tobacco-pipe clay in a small cylinder CD, fig. 4. Plate II. and insert in it two wires A, B, so that their ends within the clay may be about a fifth part of an inch from one another. If a shock be sent through this clay, by connecting one of the wires, A or B, with the outside of a charged jar, and the other with the inside, it will be inflated by the shock, *i. e.* by the spark, that happens between the two wires, and after the explosion will appear as represented fig. 5. If the shock sent through it is too strong, and the clay not very moist, it will be broken by the explosion, and its fragments scattered in every direction.

To

To make this experiment with a little variation, take a piece of the tube of a tobacco-pipe, about one inch long, and fill its bore with moist clay, then insert in it two wires, as in the above rolled clay, and send a shock through it. This tube will not fail to burst by the force of the explosion, and its fragments will be scattered about to a great distance.

If, instead of clay, the above-mentioned tube of the tobacco-pipe, or a glass tube, (which will answer as well) be filled with any other substance, either electric or non-electric, inferior to metal, on making the discharge, it will be broken in pieces with nearly the same force.

This experiment is the invention of Mr. LANE, F. R. S.

EXPERIMENT XIV.

To show the Course of the electric Fluid by the spontaneous Discharge.

Take a coated phial of a small size, and if the naked part of it, *i. e.* from its outside

side coating to the cork, is very dry, breathe upon it once or twice, so as to render it slightly damp; then holding the phial by its outside coating, present its knob to the prime Conductor, while the machine is in action, and you will see, that after the phial has received a small charge, a beautiful brush of rays will proceed from the cork, which, after going a little way into the air, turns its course towards the outside coating of the phial. If the phial, instead of the prime Conductor, be presented to the insulated rubber, then the brush, instead of proceeding from the cork, will issue from the outside coating, and direct its course towards the cork or wire of the phial; showing beyond a doubt the truth of the hypothesis of a single electric fluid.

This experiment, which is of Mr. HENRY, requires a nicety of operation, without which it will not succeed as above described. The quantity of moisture upon the phial; and the quantity of Electricity communicated by the machine, must be of

a degree, which nothing but practice can determine.

EXPERIMENT XV.

To make the electric Spark visible in Water.

Fill a glass tube, of about half an inch diameter, and six inches long, with water, and to each extremity of the tube adapt a cork, which may confine the water; through each cork insert a blunt wire, so that the extremities of the wires within the tube may be very near one another; lastly, connect one of these wires with the coating of a small charged phial, and touch the other wire with the knob of it; by which means the shock will pass through the wires, and cause a vivid spark to appear between their extremities within the tube. In performing this experiment care must be taken, that the charge be exceedingly weak, otherwise the tube will burst.

C, fig. 14. Plate II. represents a common drinking-glass almost full of water. A B are two knobbed wires so bent, that their

their knobs may be within a little distance of one another in the water. If one of these wires be connected with the outside coating of a pretty large jar, and the other wire be touched with the knob of it; the explosion which must pass through the water from the knob of one of the wires to that of the other, will disperse the water, and break the glass with a surprising violence. This experiment is very dangerous if not conducted with great caution.

F. BECCARIA constructed a small mortar, into which a drop of water was put, between the extremities of two wires which went through the sides of the mortar, and a wooden ball was applied over the drop of water; then a charged jar being discharged through the wires of the mortar, and consequently through the drop of water, rarefied the latter, and drove the ball out with considerable force. Mr. LULLIN produced a greater effect by making the discharge through oil instead of water. *Dissertatio Physica*, p. 26.

EXPERIMENT XVI.

*To prove that the electric Spark displaces
and rarefies the Air.*

Fig. 3. Plate II. represents an instrument, which the inventor, Mr. KINNER-SLEY, calls the *electrical Air Thermometer*, it being very useful to observe the effects of the electric explosion upon air. The body of this thermometer consists of a glass tube AB, about ten inches long, and nearly two inches diameter, and closed air-tight at both ends by two brass caps. Through a hole in the upper cap, a small tube HA, open at both ends, is introduced in some water at the bottom B of the large tube. Through the middle of each of the brass caps, a wire FG, EI is introduced, having a brass knob within the glass tube, and by sliding through the caps, they may be set at any distance from one another. This instrument is, by a brass ring C, fastened to the pillar of the wooden stand CD, that supports it. When the air within the
tube

tube AB is rarefied, it will press upon the water at the bottom of the tube, which will consequently rise in the cavity of the small tube; and as this water rises higher or lower, so it shows the greater or less rarefaction of the air within the tube AB, which has no communication with the external air.

If the water, when this instrument is to be used, is all at the bottom of the large tube, (*i. e.* none of it is in the cavity of the small tube) it will be proper to blow with the mouth into the small tube, and thus cause the water to rise a little in it; where, for better regulation, a mark may be fixed.

Bring the knobs GI of the wires IE, FG into contact with one another, then connect the ring E, or F with one side of a charged jar, and the other ring with the other side, by which operation a shock will be made to pass through the wires FG, IE, *i. e.* between the knobs EI. In this case you will observe, that the water in the small tube is not at all moved from

the mark; which shows, that the passage of the electric fluid through Conductors sufficiently large, occasions no rarefaction, nor displaces the air about them.

Put the knobs G, I a little distant from one another, and send a shock through them as before, and you will see that the spark between the two knobs, not only displaces, but rarefies considerably the air; for the water will be suddenly pushed almost to the top of the small tube, and immediately it will subside a little, as for instance as far as H; which is occasioned by the sudden displacing and replacing of the air about the place, where the spark appeared within the tube A B. After that the water has subsided suddenly from the first rising, it will then gradually and slowly come down to the mark at which it stood before the explosion; which is the effect of the air that was rarefied, and which gradually returns to its former temperature.

If this experiment be made in a room, where the degree of heat is variable, then
proper

proper allowance must be made for this circumstance, in estimating the event of the experiment; for the electrical air thermometer is affected by heat, or cold in general, as well as by that caused by an electric spark.

EXPERIMENT XVII.

To fire Gun-powder.

Make a small cartridge of paper, and fill it with gun-powder, or else fill the tube of a quill with it; insert two wires, one at each extremity, so that their ends within the quill, or cartridge, may be about one fifth of an inch from one another; this done, send the charge of a phial through the wires, and the spark between their extremities, that are within the cartridge, or quill, will set fire to the gun-powder. If the gun-powder be mixed with steel filings, it will take fire more readily, and with a very small shock,

EXPERIMENT XVIII.

To light a Candle by the Discharge of a Jar.

Take a wire of the size of a common knitting-needle, and by means of a small flexible wire or a chain, let one end of it communicate with the outside of a jar, that at least contains about ten inches of coated surface. To the other end of the thick wire some cotton must be twisted, but very loosely, so as to form a head round, and to conceal the extremity of the wire entirely. This head of cotton must be rolled in powder of lycopodium, or, which answers better, in powder of rosin; by which means a good deal of the powder will stick to the cotton:—this done, the jar is charged, and then the head of cotton, &c. is brought towards its knob rather quickly, so as to cause the jar to discharge through the cotton, by which means the cotton will be instantly set on fire, and will last long enough to light a candle thereby.—This is a very pleasing experiment, contrived by Dr. INGENHOUSZ.

EXPE-

EXPERIMENT XIX.

To strike Metals into Glass.

Take two slips of common window-glass about three inches long, and half an inch wide ; put a small slip of gold, silver, or brass leaf, between them, and tie them together, or else press them together between the boards of the press H, belonging to the universal discharger, fig. 5. Plate I. leaving a little of the metallic leaf out between the glasses at each end ; then send a shock through this metallic leaf, and the force of the explosion will drive part of the metal into so close a contact with the glass, that it cannot be wiped off, or even be affected by the common menstrua, which otherwise would dissolve it.

In this experiment the glasses are often shattered to pieces ; but whether they are broken or not, the indelible metallic tinge will always be found in several places, and sometimes through the whole length of both glasses.

EXPERIMENT XX.

To stain the Paper, or Glass.

Lay a chain, which forms a part of the circuit between the two sides of a charged jar, upon a sheet of white paper, and if a shock be sent through it, the paper will be found stained with a blackish tinge at every juncture of the links. If the charge be very large, the paper, instead of being stained with spots, is burnt through. If the chain be laid upon a pane of glass, instead of paper, the glass will often be found stained with spots in several places, but (as might be expected) not so deep as the paper.

If this experiment be made in the dark, a spark will be seen at every juncture of the links, from which place a kind of radiation also proceeds; and if the links are small, and the shock pretty strong, the chain will appear illuminated like a line of fire; which shows that the electric fluid meets with some resistance in passing from one link of the chain to another,

EXPE-

EXPERIMENT XXI.

The lateral Explosion.

If a jar be discharged with a discharging rod that has no electric handle, the hand that holds it, in making the discharge, feels some kind of shock, especially when the charge is considerable.—In other words: A person, or any conducting substance, that is connected with one side of a jar, but forms no part of the circuit, will feel a kind of shock, *i. e.* some effect of the discharge. This may be rendered visible in the following manner. Connect with the outside of a charged jar a piece of chain; then discharge the jar through another circuit, as for instance, with a discharging rod in the common way, and the chain that communicates with the outside of the jar, and which makes no part of the circuit, will appear lucid in the dark, *i. e.* sparks will appear between the links; which shews that the electric fluid natural to that chain, must by some means have been

been disturbed. This chain will also appear luminous, if it is not in contact with the outside of the jar, but only very near it; and on making the discharge, a spark will be seen between the jar and the end of the chain near it. This electrical appearance out of the circuit of a discharging jar, is that which we call the *lateral Explosion*: and to make it appear in the most conspicuous manner, observe the following method, which is of Dr. PRIESTLEY,

When a jar is charged, and stands upon the table as usual, insulate a thick metallic rod, and place it so that one of its ends may be contiguous to the outside coating of the jar; and within about half an inch of its other end, place a body of about six or seven feet in length, and a few inches in breadth; then put a chain upon the table, so that one of its ends may be about one inch and a half distant from the coating of the jar; to the other end of the chain apply one knob of the discharging rod, and bring the other knob to the wire of the jar in order to make the explosion. On making the discharge in this manner, a strong spark will be seen
between

between the insulated rod, which communicates with the coating of the jar, and the body near its extremity, which spark does not alter the state of that body in respect to Electricity; hence it is imagined, that this lateral spark flies from the coating of the jar, and returns to it at the same instant, allowing no perceptible space of time, in which an electrometer can be affected. Whether this lateral explosion is received on flat and smooth surfaces, or upon sharp points, the spark is always equally long and vivid.

The cause of this phenomenon seems to be the interruption in the circuit, made by introducing bad Conductors into it; for, as this interruption is greater or less, so the lateral explosion is more or less considerable.

C H A P. VIII.

Experiments with other charged Electrics.

THAT the experiments made with other charged electrics are similar to those made with charged glass, is very evident; since it has been observed above in the First Part, and also in the experiments already described, that the property of being charged, of exploding, &c. is not inherent in glass, as glass, but, as being impervious to the electric fluid; and in consequence, it must be common to all such substances, which, like glass, are impervious to that fluid: therefore, under the title of experiments with other electrics, I mean to describe experiments, not of a different nature from the above-mentioned, but only the manner of coating and using other electrics, which are not so manageable as glass, but at the same time, have some peculiar advantages. These methods I shall reduce to three, *i. e.* first, that of making the experiment of charging

charging a plate of air; secondly, the method of coating resinous substances; and lastly, a method of trying other electrics, that are in a fluid state.

EXPERIMENT I.

To charge a Plate of Air.

Take two smooth circular boards, quite plain, and each about three or four feet in diameter; coat one side of each with tin-foil, which should be pasted down, burnished, and turned over the edge of the board. These boards must be both insulated, parallel to one another, in an horizontal position; they must be turned with their coated sides towards each other, and should be placed in such a manner as to be easily removed to or from each other; to do which, it will be proper to fix to one of the boards a strong supporter, of glass or baked wood, and to suspend the other by silk strings from the cieling of the room; from which, by a proper pulley, it may be lowered or raised, so as to be at any required distance from the lower board, which may be placed upon a table.

When

When these boards are placed in the manner above described, and at about one inch distance from one another, they may be used exactly as the two coatings of a pane of glass. If one of the boards is connected with the electrified prime Conductor, and the other be left insulated, they will receive no charge, agreeable to the second experiment of the preceding chapter; and if after some time you touch them, you will receive only a spark from the upper board, in consequence of its being connected with the electrified prime Conductor. If, whilst one of the boards is receiving Electricity, the other communicates with the earth, then the plate of air between them will be charged, like a coated plate of glass; for that board which communicates with the earth will acquire an Electricity contrary to that of the other board; and if you touch them, *i. e.* make a communication between them, they will explode, give the shock, &c. similar to a charged jar.

In this experiment it cannot be expected, that such an explosion, and with such a

force, will be produced, as by an equal surface of coated glass; for here the coatings cannot be brought so near one another as to render them capable of a high charge, because the plate of air, being much less compact than glass, may be easily broken by the force of the charge, *i. e.* it may easily discharge itself. Notwithstanding, however, that a plate of air is not capable of receiving a very high charge, yet this experiment has a great advantage, which is, that here we may see what passes between the two coatings, either in charging or discharging the plate of air; and we may introduce several things into the substance of this coated electric, which produce several remarkable appearances. By this experiment the true state of the earth, when covered by electrified clouds, may be represented exceedingly well; and several meteors, that happen in that state, and which are thought to be effects of Electricity, may be imitated; such as water-spouts and whirlwinds, besides the well-known electrical phenomena, thunder and lightning.

In

In order to represent a water-spout, as it is often observed at sea, place the two boards at about two inches distance from one another; put a large drop of water about the middle of the lowest of them, and fix a metallic ball, or any other piece of metal that is somewhat spherical *, to the upper board, just opposite to, and at about half an inch distance from the surface of the water. If in this situation the upper board be electrified, whilst the lower communicates with the earth, the water, which represents the sea, will be attracted by the metallic ball, which represents a cloud, and rising nearly in a conical body, will afford a pretty good representation of the water-spout †.

The
 * The metallic covering of some kind of coat-buttons answers exceedingly well, and may be pasted on the tin-foil coating of the board.

† The knob of a charged bottle, being brought near the water in a metal plate, or common earthen-ware faucer, shews this experiment in a simple and beautiful manner. If a large drop of water be placed upon the knob of an insulated charged bottle, and the knob of another bottle, charged with the contrary Electricity, be brought near the drop of water, it will be squirted

The appearance of a whirlwind is but seldom, and by chance to be observed. The bran between the two plates, F, P, fig. 2. Plate I, is sometimes whirled like the dust in a whirlwind; but there is no certain rule, that I know, for producing this phenomenon.

In order to succeed in this experiment, Mr. BECKET directs to place the boards above mentioned about four or five inches asunder, and to put some bran, and very small bits of paper, about the center of the lower board. If in this situation the upper board be connected with the electrified prime Conductor, and the lower be either connected with the ground or with the rubber of the machine, the bran, and bits of paper, will be attracted and repelled, alternately, by the boards. “ But (says “ Mr. BECKET *) the most surprising appearance in this experiment, and what “ gives it the most exact resemblance of a

squirted away in a curious manner, particularly if the coating of the insulated bottle be touched at the same time.

* In his Essay on Electricity, p. 141.

“ whirlwind, is that sometimes, when the
 “ Electricity is very strong, a quantity of
 “ the paper and bran will accumulate in
 “ one place, forming a kind of column
 “ between the boards, and suddenly ac-
 “ quire a swift horizontal motion, moving
 “ like a whirling pillar to the edge of the
 “ boards, and from thence fly off, and be
 “ scattered about the room to a consider-
 “ able distance. I own I am entirely at a
 “ loss to account for this extraordinary ap-
 “ pearance — I call it extraordinary, be-
 “ cause it but seldom occurs, and seems to
 “ depend either on a certain degree of at-
 “ traction, quantity of the bran, or dis-
 “ tance between the boards ; and I could
 “ seldom get it to succeed perfectly but by
 “ accident.”

The phenomena of thunder and light-
 ning are exhibited at the same time by a
 spontaneous discharge of the plate of air ;
 which may be easily produced by setting
 the boards at about an inch distance from
 each other, and electrifying them strongly.

EXPERIMENT II.

To coat resinous Electrics.

The best method to coat such electrics as rosin, sealing-wax, &c. that can easily be melted, is first to put a circular piece of tin-foil, about two inches less in diameter than the plate you intend to make, upon a marble table; then, to pour over it the electric just melted. This may be spread and flattened by pressing it with a pane of glass, or any thing that is even and smooth; afterwards, another piece of tin-foil, equal to the former, is to be stuck upon the electric, which may be done by pressing it gently with a hot iron; and then the plate, which may be easily separated from the marble table, will be fit for use.

EXPERIMENT III.

To insulate fluid Electrics.

Take a large earthen dish, flat at the bottom, and stick within it a piece of tin-

foil about an inch shorter than the flat part of the dish all around, and through a small hole, made in the bottom of the dish, introduce a slender wire, which must communicate with the tin-foil; then pour into the dish some melted tallow, or other electric substances that you desire to try; lastly, let a round brass plate*, equal to the tin-foil stuck in the dish, and either proceeding from a glass arm or from the prime Conductor, just touch the surface of the electric in the dish, and let it stand parallel, and opposite to the tin-foil stuck in its bottom. In this manner the plate of liquid electric is coated, and may be easily subjected to experiments.

Plates of other consistent electrics, that cannot easily be melted, may be coated in the same manner as a plate of glass; and some of them will be found to answer as well, if not better than glass.

* The brass plate F, fig. 2. of Plate I. may be very useful for this purpose.



C H A P. IX.

Experiments on the Influence of Points, and the Usefulness of pointed metallic Conductors, to defend Buildings from the Effects of Lightning.

MY reader, in the course of this work, must have observed in several of the experiments already described, the remarkable property that points have, both of throwing off and receiving *silently* the electric fluid; but in this chapter I shall describe some more curious experiments of this kind, by which the influence of points, in respect to Electricity, may be better understood, and which may, in a more particular manner, demonstrate the utility of metallic Conductors to houses, or piles of building, in order to preserve them from the damage often occasioned by a stroke of lightning; which is one of the greatest benefits that mankind has received from the science of Electricity.

U 3

EXPERIMENT

EXPERIMENT I.

To discharge a Jar silently.

When a large jar is fully charged, which would give a terrible shock, put one of your hands in contact with its outside coating; with the other hold a sharp-pointed needle, and, keeping the point directed towards the knob of the jar, proceed gradually near it, until the point of the needle touches the knob. This operation discharges the jar entirely, and you will either receive no shock at all, or so small a one as can hardly be perceived. The point of the needle, therefore, has silently and gradually drawn all the superfluous fluid from the inside surface of the electric jar.

EXPERIMENT II.

Drawing the Electricity from the prime Conductor by a Point.

Let a person hold the knob of a brass rod at such a distance from the prime Conductor,

Conductor, that sparks may easily fly from the latter to the former, when the machine is in motion. Then let the winch be turned, and, while the sparks are following one another, present the sharp point of a needle, at nearly twice the distance from the prime Conductor that the knobbed rod is held; and you will observe that no more sparks will go to the rod;—remove the needle entirely, and the sparks will be seen again;—present the needle, and the sparks disappear; which evidently shows, that the point of the needle draws off *silently* almost all the fluid that the cylinder throws upon the prime Conductor.

If the needle be fixed upon the prime Conductor with the point outward, and the knob of a discharging rod, or the knuckle of a finger, be brought very near the prime Conductor, though the excitation of the cylinder may be very strong, yet you will perceive that no spark, or only an exceeding small one, can be obtained from the prime Conductor.

EXPERIMENT III.

The electric Fly.

Fix the fly, described in the third chapter, upon the prime Conductor, as represented by D, fig. 2, of Plate I; then turn the winch of the machine, and the fly will immediately begin to move round in an horizontal position, and in the direction of the letters *a b c d*; *i. e.* contrary to the direction of the points of the wires. If the experiment is repeated with a Conductor negatively electrified, the fly will turn the same way as before, *viz.* in the direction of the letters *a b c d*. The reason of this experiment depends upon the repulsion existing between bodies possessed of the same Electricity; for whether the fly is electrified positively or negatively, the air opposite to the points of the wires (on account of the points easily transmitting Electricity) acquireth a strong Electricity, analogous to that of the points; and therefore the air and the points must repel each other. This explanation is confirmed, by observing

observing that the above fly not only does not move in vacuo; but even, if placed under a close receiver, it will turn but for a little while, and then stop; for the quantity of air contained in the receiver, may become readily, and equally electrified*.

EXPERIMENT IV.

The electrified Cotton.

Take a small lock of cotton, extended in every direction as much as conveniently can be done, and by a linen thread about

* If, when the fly under the close receiver is stopped, you put the end of a finger on the outside of the glass, opposite to one of the points of the fly, this will move again briskly; and by altering the position of your finger occasionally round the glass, you may continue its action a considerable time, viz. till most of that part of the glass is charged. In this case, when the finger is applied on the outside of the receiver, the glass losing part of its natural electric fluid from the outside (*i. e.* if the fly is electrified positively, or *vice versa*, if negatively) receives the fluid of the electrified air on its inside surface; hence this air is put in a state of being again electrified by the point of the fly, which renews the motion.

five or six inches long, or by a thread drawn out of the same cotton, tie it to the end of the prime Conductor; then let the winch of the machine be turned, and the lock of cotton, on being electrified, will immediately swell, by repelling its filaments from one another, and will stretch itself towards the nearest Conductor. In this situation, let the winch be kept turning, and present the end of your finger, or the knob of a wire, towards the lock of cotton, which will then immediately move towards the finger, and endeavour to touch it; but take with the other hand a pointed needle, and present its point towards the cotton, a little above the end of the finger, and you will observe the cotton immediately to shrink upward, and move towards the prime Conductor. Remove the needle, and the cotton will come again towards the finger. Present the needle, and the cotton will shrink again: which clearly shews, that the needle, being sharp-pointed, draws off the electric fluid from the cotton, and puts it in a state of being attracted by the prime Conductor; which could not be effected by a wire having a blunted

blunted end, or a round ball for its termination,

EXPERIMENT V.

The electrified Bladder.

Take a large bladder, well blown, and cover it with gold, silver, or brass leaf, sticking it with gum-water; suspend this bladder at the end of a silk thread, at least six or seven feet long, hanging from the ceiling of the room, and electrify the bladder, by giving it a strong spark with the knob of a charged bottle: this done, take a knobbed wire, and present it to the bladder when motionless, and you will perceive, that as the knob approaches the bladder, the bladder also moves towards the knob, and when nearly touching it, gives it the spark, which it received from the charged phial, and thus it becomes un-electrified. Give it another spark, and, instead of the knobbed wire, present the point of a needle towards it, and you will perceive that the bladder will not be attracted by, but rather recede from the point,

point, especially if the needle be very suddenly presented towards it.—This is one of Mr. HENLY's experiments.

Before we proceed to the practical use of pointed Conductors to buildings, in order to defend them from lightning (which is nothing more than the proper application of the preceding experiments) it will be proper to say something in explanation of the above property of points, which has lately occasioned several controversies. In order to this, it should be remembered, that the electric fluid superinduced upon an insulated body, is confined upon that body by the air which surrounds it. Further, that Electricity, by being continually communicated to the air, which is never a perfect electric, is gradually dissipated; from whence follows this very evident principle, *i. e.* that as a greater or less quantity of air is contiguous to a given quantity of electrified surface, so that surface loseth its Electricity sooner or later. Suppose, for instance, that a pointed needle is fixed upon the prime Conductor; mark a dot upon any part of the prime Conductor,

tor, which may be nearly equal to the point of the needle, and then electrify the prime Conductor. Now it is evident to bare inspection, that although the point of the needle and the dot, &c. are of equal surfaces, yet the former is exposed to a quantity of air, which almost entirely surrounds it, and which is vastly greater than the air contiguous to the latter: hence, the Electricity, communicated to the prime Conductor, is dissipated more easily from the point of the needle than from the dot, or any other part of the prime Conductor. Besides, the air about the point may more easily be moved, in consequence of the electrical repulsion, than at any other part of the surface of the prime Conductor, and new air, *i. e.* unelectrified air, passes more frequently by it, which taking always part of the Electricity of that body, promotes also its dissipation.

In the same manner may be understood, why the Electricity is more easily dissipated at sharp edges and corners, than at flat ones; for as the surfaces of bodies in general are more or less plain, so they are exposed

exposed to a less or greater quantity of air, and participate more or less of the nature and properties of points.

When the pointed body is negatively electrified, it is for the same reason that it acquires the electric fluid through the point, easier than through any other part of its surface; *i. e.* because the point exhibiting the least surface to the greatest quantity of free air, has the greatest number of particles of air, from which it can extract the electric fluid *.

EXPERIMENT VI.

The Thunder-house.

Fig. 1. of Plate II. is an instrument representing the side of a house, either furnished with a metallic Conductor, or not; by which both the bad effects of lightning striking upon a house not properly secured, and the usefulness of metallic Con-

* For a more particular explanation of the above-mentioned property of points, see BECCARIA's Artificial Electricity.

ductors,

ductors, may be clearly represented. A is a board about three quarters of an inch thick, and shaped like the gable-end of a house. This board is fixed perpendicularly upon the bottom board B, upon which the perpendicular glass pillar CD is also fixed, in a hole about eight inches distant from the basis of the board A. A square hole, ILMK, about a quarter of an inch deep, and nearly one inch wide, is made in the board A, and is filled with a square piece of wood, nearly of the same dimensions. I mention nearly of the same dimensions, because it must go so easily into the hole, that it may drop off by the least shaking of the instrument. A wire, LK, is fastened diagonally to this square piece of wood. Another wire, IH, of the same thickness, having a brass ball, H, screwed on its pointed extremity, is fastened upon the board A; so also is the wire MN; which is shaped in a ring at O. From the upper extremity of the glass pillar CD, a crooked wire proceeds, having a spring socket F, through which a double-knobbed wire slips perpendicularly, the lower knob G of which falls just
above

above the knob H. The glass pillar DC must not be made very fast into the bottom board; but it must be fixed so as it may be pretty easily moved round its own axis, by which means the brass ball G may be brought nearer or farther from the ball H, without touching the part E F G. Now when the square piece of wood LMIK (which may represent the shutter of a window or the like) is fixed into the hole so, that the wire LK stands in the dotted representation IM, then the metallic communication from H to O, is complete, and the instrument represents a house furnished with a proper metallic Conductor; but if the square piece of wood LMIK is fixed so, that the wire LK stands in the direction LK, as represented in the figure, then the metallic Conductor HO, from the top of the house to its bottom, is interrupted at IM, in which case the house is not properly secured.

Fix the piece of wood LMIK, so that its wire may be as represented in the figure, in which case the metallic Conductor HO is discontinued. Let the ball G be

be fixed at about half an inch perpendicular distance from the ball H, then, by turning the glass pillar DC, remove the former ball from the latter: by a wire or chain connect the wire EF with the wire Q of the jar P, and let another wire or chain, fastened to the hook O, touch the outside coating of the jar. Connect the wire Q with the prime Conductor, and charge the jar; then, by turning the glass pillar DC, let the ball G come gradually near the ball H, and when they are arrived sufficiently near one another, you will observe that the jar explodes, and the piece of wood, LMIK, is pushed out of the hole to a considerable distance from the thunder-house. Now the ball G, in this experiment, represents an electrified cloud; which, when it is arrived sufficiently near the top of the house A, the Electricity strikes it, and, as this house is not secured with a proper Conductor, the explosion breaks part of it, *i. e.* knocks off the piece of wood IM.

Repeat the experiment with only this variation, *viz.* that this piece of wood IM

X

is

is situated so, that the wire LK may stand in the situation IM; in which case the Conductor HO is not discontinued; and you will observe, that the explosion will have no effect upon the piece of wood LM; this remaining in the hole unmoved; which shews the usefulness of the metallic Conductor.

Further: Unscrew the brass ball H from the wire HI, so that this may remain pointed, and, with this difference only in the apparatus, repeat both the above experiments; and you will find that the piece of wood IM is in neither case moved from its place, nor any explosion will be heard; which demonstrates the preference of Conductors with pointed terminations to those with blunted ones.

To prove farther the preference of pointed Conductors to blunt ones, the experiment of the electrified cotton (*viz.* the fourth experiment of this chapter) may be easily repeated with this apparatus; by which it may be shewn, that a pointed Conductor silently drawing off the electric fluid from
the

the small clouds near it, which are represented by the cotton tied to the wire of the ball G, repels them, and may thus, in some cases, perhaps, actually prevent a stroke of lightning; whereas the blunted Conductor facilitates it. Small feathers may also be tied near the knob G, which, by repelling one another, may exhibit a better representation of an electrified cloud; and in short, with a little contrivance, the above-described apparatus, commonly called the *Thunder-house*, may be adapted to represent the principal phenomena of lightning, together with several circumstances preceding, or following it.

C H A P. X.

Experiments with the electrical Battery.

THE force of accumulated Electricity, great as it appears by the experiments performed with a single coated jar, is very small when compared with that, which is produced by a number of jars connected together; and if the effects of a single jar are surprising, the prodigious force of a large battery is certainly astonishing. To observe that the metals, even the most purified platina, which resists the greatest efforts of chemic fire, are actually, and almost instantaneously rendered red-hot, and fused; to see animals destroyed; and to hear the loud report of a large electric battery, are things that always produce a kind of terror in the mind of an attentive observer. Experiments of this kind should be conducted with great caution, and the Operator ought to be attentive, not only to the business in hand, but also to the persons who may happen to be near him, prohibiting their touching, or even coming too
near

near any part of the apparatus ; for if a mistake in performing other experiments may be disagreeable, those in the discharge of a large battery may be attended with worse consequences.

When a battery is to be charged, instead of a large prime Conductor, a small one is much more convenient ; for, in this case, the dissipation of the Electricity is not so considerable. The quadrant electrometer, which shews the height of the charge in the battery, may be fixed either upon the prime Conductor, or upon the battery ; in which latter case, it should be placed upon a rod proceeding from the wires of the jars, and if the battery be very large, it should be elevated two or three feet above them.

The index of the electrometer in charging a large battery will seldom rise so high as 90° , because the machine cannot charge a battery so high in proportion, as a single jar. Its limit is often about 60° or 70° , more or less in proportion to the size of the battery, and the force of the machine.

EXPERIMENT I.

To melt Wires.

Connect with the hook, communicating with the outside coating of a battery, containing at least thirty square feet of coated surface, a wire, that is about one fiftieth part of an inch thick, and about two feet long; the other end of it must be fastened to one end of the discharging rod; this done, charge the battery, and then, by bringing the discharging rod near its wires, send the explosion through the small wire, which, by this means, will be made red-hot, and melted, so as to fall upon the floor in different glowing pieces. When a wire is melted in this manner, sparks are frequently seen at a considerable distance from it, which are red-hot particles of the metal, that by the violence of the explosion are scattered in all directions. If the force of the battery is very great, the wire will be intirely dispersed by the explosion, so that none of it can be afterwards found.

By

By repeating this experiment with wires of different metals, and the same force of explosion, it will be found that some metals are more readily fused than others, and some not at all affected; which shows the difference of their conducting power. If it be required to melt such particles of metals, that cannot easily be drawn in wires, as ores, grains of platina, &c. they may be set in a train upon a piece of wax; this train may be inserted in the circuit, and an explosion may be sent through it, which, if it is sufficiently strong, will melt the metallic particles, as well as the wires: or, if the quantity to be tried be large enough, it may be confined in a small tube of glass.

In melting wires of a considerable length, it is often observed, that when the force of the explosion is just sufficient to render the wire red-hot, the redness begins first from one end of it, namely, that which communicates with the positive side of the battery, and from thence gradually proceeds to the other end. This is another ocular demonstration of the theory of a single electric fluid. Indeed the wire is not rendered red-

hot in one place before the other, in consequence of the electric fluid passing first through the former, and then through the latter, for that difference of time is by far too small to be observed; but, because the electric fluid loses some of its impetus, or velocity, in going through the wire; hence the part of the wire which the electric fluid enters, suffers the greatest effect of the shock, and, consequently, becomes red sooner, and in a greater degree.

If a wire is stretched by weights, and a shock is sent through it, which renders it just red-hot, the wire, after the explosion, will be found considerably lengthened; but if the wire is left loose, after a similar explosion it will be found shortened*. If a wire is melted upon a piece of glass, the glass, after the explosion, will be found marked with all the prismatic colours.

* This is a late observation of Mr. EDWARD NAIRNE. See the Phil. Trans. vol. LXX.



EXPERIMENT II.

To shew that the electric Fluid prefers a short Passage through the Air, to a long one through good Conductors.

Bend a wire about five feet long in the form represented by fig. 11. Plate II. so that the parts AB may come within half an inch of one another; then connect the extremities of the wire with the hook of the battery, and the discharging-rod, as directed in the preceding experiment, and send the charge of a battery through it. On making the explosion, a spark will be seen between A and B, which shows that the electric fluid chooses rather a short passage through the air, than the long one through the wire. The charge, however, does not pass intirely through A and B, but part of it goes also through the wire; which may be proved by putting a slender wire between A and B; for, on making the discharge with only this addition in the apparatus, the small wire will be hardly made red-hot; whereas, if the large wire ADB
be

be cut in D, so as to discontinue the circuit ADB, the small wire will be melted, and even exploded, by the same shock that before made it scarcely red-hot. In this manner (says Dr. PRIESTLEY, who is the inventor of this experiment) may the conducting power of different metals be tried, using metallic circuits of the same length and thickness, and observing the difference of the passage through the air in each.

EXPERIMENT III.

To make Globules of Metals.

Take a very slender wire, and put it in a glass tube, about one quarter of an inch in diameter; then send the charge of a battery through it, and the wire will be melted, and reduced into globules of different sizes, which are found sticking on the inside surface of the glass tube, and they may be easily separated from it at pleasure: these, upon examination, will all be found hollow, and are little more than a mere scoria of metal.

It

It must be observed, in making this experiment, that the charge of the battery must neither be too high nor too weak; for in the former case, the wire will be reduced into pieces exceedingly small, or rather exploded in smoke; and in the latter case, it will be imperfectly fused, so that its pieces will be large and irregular.

EXPERIMENT IV.

The Fairy Circles.

Fix upon each of the knobs DD of the universal discharger, fig. 5. Plate I. or upon the wires that support the knobs, if the knobs are removed, a flattish and smooth piece of metal, or semi-metal (watch-cases are very fit for this purpose) so that their surfaces may come so near each other, that the battery may be discharged through them; then connect one wire of the discharger with the outside of the battery, and the other wire, by the help of the discharging rod, with the inside of it, so as to make the discharge; which will occasion the spot and circles described in
the

the first part of this Treatise, upon the surface of each of the pieces of metal fixed upon the discharger.

These circles have hitherto been exhibited upon the surface of no other substances but metals; and they are found to be marked more distinctly upon such metals as melt with the least heat. The most beautiful of these rings are produced by a number of discharges from a large battery, every part of the apparatus remaining exactly in the same situation. If the pieces of metal receive the explosion in vacuo, the spot formed on them is very irregular and confused.

I have given these spots the appellation of *Fairy Circles*, on account that they bear some resemblance to the spots so called, which are often observed upon the grass in the fields. These, which we may call natural Fairy Circles in the fields, have been thought to be effected by lightning, on account of their bearing some resemblance to the above-mentioned circles produced by Electricity; the supposition, however,

however, seems not very probable; for the spots in the fields, called Fairy Circles, have no central spot, no concentric circles, neither are they always of a circular figure; and, as I am informed, they seem to be rather beds of mushrooms than the effects of lightning.

EXPERIMENT V.

To mark coloured Rings on Metals.

In order to exhibit coloured rings upon the surface of metals, place a plain piece of any of the metals upon one of the wires of the universal discharger, and upon the other wire fix a sharp-pointed needle, with the point just opposite to the surface of the metal; then connect one wire of the discharger with the outside of a battery, and the other with the discharging-rod, &c. In this manner, if explosions are repeatedly sent either from the point to the piece of metal, or from the latter to the former, they will gradually mark the surface of the piece of metal opposite to the point with circles, consisting of all the prismatic

prismatic colours; which are evidently occasioned by laminæ of the metal, raised by the force of the explosions.

These colours appear sooner, and the rings are closer to one another, when the point is nearer to the surface of the metal. The number of rings is greater or less, according as the point of the needle is more sharp or more blunt; and they are represented equally well upon any of the metals.

The point of the needle is also coloured to a considerable distance; the colours upon it returning in circles, though not very distinctly. This is an experiment of Dr. PRIESTLEY.

EXPERIMENT VI.

The Imitation of an Earthquake.

The appearance of the earthquake, as represented with the explosion of a battery, is occasioned by the concussion given to several substances by the explosion

passing over their surfaces. To give a representation of the impressiion made upon houses by the earthquake, small sticks, cards, or the like, may be placed upon the surface of the body over which the explosion is to be transmitted, so as to stand very light. These sticks, &c. will never fail to be shook, and often to be thrown down by the explosion.

It is remarkable, that an explosion will not pass over the same length of surface of all bodies, though they are equally good Conductors. Water, ice, wet wood, raw flesh, and most of the animal fluids, are the best to make this remarkable experiment; to do which, nothing more is required than to insert part of the surface of the said substances into the circuit of the two sides of a battery; a chain, for instance, communicating with the outside, may be placed so as nearly to touch the surface of a quantity of water, and at about eight or nine inches distant * from another

* The distance at which an explosion will strike over the surface of the above-mentioned substances, is much greater than that it can strike through in air only.

chain,

chain, situated also very near the surface of the water, and communicating with one end of the discharging-rod. If the ends of the chains touch the water, the experiment will happen in the same manner.

The report, in this experiment, is much louder than when the explosion passes through the air only. The concussion given to the water, by the explosion passing over its surface, is not only superficial, but affects its whole body; and if the hand is kept deep under its surface whilst the explosion passes over it, the concussion may be very sensibly felt.

The spark, that in this experiment passes over the surface of the water, seems to bear a great resemblance to the balls of fire that have sometimes been seen over the surface of the sea or land in time of an earthquake; and hence it seems very probable, that those balls of fire are electrical phenomena.

CHAP. XI.

Promiscuous Experiments.

EXPERIMENT I.

To shew that Smoke, and the Vapour of hot Water, are Conductors.

LET a cork-ball electrometer be suspended about four or five feet above the prime Conductor, then turn the winch of the machine very gently, and you will find, that the balls of the electrometer will not diverge. Put upon the prime Conductor a wax-taper * just blown out, so that its smoke may ascend to the electrometer; then turn the winch again, and the balls of the electrometer will immediately separate a little, with the same force of Electricity, from the prime Conductor; which shews that smoke is a Conductor in a small degree.

* A green wax-taper is the best for this experiment.

In the same manner, by placing a small vessel with hot water upon the prime Conductor, instead of the wax-taper, it may be proved, that its vapour is also a Conductor; but inferior in its conducting power to the smoke. This experiment is an invention of Mr. HENLY.

EXPERIMENT II.

To prove that Glass, and other Electrics, become Conductors, when they are made very hot.

Take a small glass tube of about one twentieth of an inch in diameter, and above a foot long; close it at one end, and introduce a wire into it, so that it may be extended through its whole length: let two or three inches of this wire project above the open end of the tube, and there fasten it with a bit of cork; tie round the closed end of the tube another wire, which will be separated from the wire within the tube only by the glass interposed between them. In these circumstances endeavour to send a shock through the two wires;

i. e.

i. e., the wire inserted in the glass tube, and that tied on its outside, by connecting one of them with the outside, and touching the other with the knob of a charged jar, and you will find that the discharge cannot be made, unless the tube be broken; because the circuit is interrupted by the glass at the end of the tube, which is interposed between the two wires. But put that end of the tube to which the wire is tied into the fire, so that it may become just red-hot, then endeavour to discharge the jar again through the wires, and you will find that the explosion will be easily transmitted from wire to wire, through the substance of the glass, which, by being made red-hot, is become a Conductor.

In order to ascertain the conducting quality of hot resinous substances, oils, &c. bend a glass tube in the form of an arch *CEFD*, fig. 7. Plate II. and tie a silk string *GCD* to it, which serves to hold it by when it is to be set near the fire; fill the middle part of this tube with rosin, sealing-wax, &c. then introduce two wires *AE*, *BF*, through its ends, so that they

may touch the rosin, or penetrate a little way in it. This done, let a person hold the tube over a clear fire, so as to melt the rosin within it; at the same time, by connecting one of the wires, A or B, with the outside of a charged jar, and touching the other with the knob of the jar, endeavour to make the discharge through the rosin, and you will observe that, while the rosin is cold, no shocks can be transmitted through it; but it becomes a Conductor according as it melts, and when totally melted, the shocks will pass through it very freely.

EXPERIMENT III.

To shew that hot Air is a Conductor.

Electrify one of the cork-ball electrometers suspended upon the stand, fig. 4. of Plate I. or electrify the prime Conductor with the quadrant electrometer; then bring a red-hot iron within a sufficient distance of the electrometer, or prime Conductor, and you will find that they soon lose their Electricity, which is certainly

tainly conducted by the hot air contiguous to the iron; for if the experiment be repeated with the same iron when cold, *i. e.* by bringing it within the same distance of the electrified Electrometer, or prime Conductor, their Electricity will not be conducted away as before *.

The above experiments may reasonably induce us to suspect, that several substances which are ranged among Conductors, would become Electrics, if they were brought into a cold temperature; and that all the Electrics become Conductors, when they are heated in a very high degree.

* It has been often observed, that a battery may be discharged, by introducing a red-hot iron between two knobs interposed, and standing at some distance from each other in the circuit; but if, instead of iron, there be introduced a piece of red-hot glass between the knobs (the distance between them remaining as at first) the battery cannot be discharged: whence we may infer, that either hot air is not so good a Conductor as has been imagined, or else, that air heated by iron (perhaps from its ignited particles) is stronger, with respect to its conducting power, than when heated by the red-hot glass.

EXPERIMENT IV.

To shew that Silks of different Colours acquire different Electricities.

Lay a white ribbon upon another ribbon of the same size and fineness, but black; then holding them by one extremity with one hand, draw them swiftly between the first and second finger of the other hand, by which friction they will be both electrified, and on being separated, the black ribbon will be found to be negative, and the white positive.

EXPERIMENT V.

To electrify the Air of a Room.

The air surrounding the electrical machine when in use, or contiguous to every highly-electrified body, always acquires a portion of Electricity, which it retains for a considerable time, and which, in some measure, counteracts the Electricity

city of electrified bodies*. A very expeditious method, however, to electrify the air, is to fix two or three needles upon the prime Conductor, and to keep it strongly electrified for about ten minutes. If afterwards an electrometer be brought into the air surrounding the apparatus, it will plainly shew, that the air has acquired a considerable quantity of Electricity, which it will retain even after the apparatus has been removed into another room. To electrify the air negatively, connect the pointed needles with the rubber when insulated; and make a communication by a chain, or wire, from the prime Conductor to the table.

Another method of electrifying the air is, to charge a large jar, and insulate it: then connect a sharp-pointed wire, or a number of them, with the knob of the jar; and make a communication from the outside coating to the table. If the jar be charged positively, the air of the room will soon become strongly electrified positively

* An electrometer suspended to the prime Conductor, will diverge most after a few turns of the wheel; but afterwards the divergence will lessen, according as the air about the apparatus becomes electrified.

likewise; but if the jar be charged negatively, the air will become also negative. A charged jar being held in one hand, and the flame of a candle, insulated, and held in the other, being brought near the knob of the jar, will also soon produce the same effect.

EXPERIMENT VI.

The Atmosphere of Smoke.

Take a brass ball, or any piece of metal that is free from points or edges, of about three or four inches diameter, and insulate it upon a narrow electric stand; then give it a spark with the knob of a charged phial, and immediately present to it a wax-taper just blown out and smoking. The smoke, in this case, will be attracted by the electrified body, and, by encompassing that body, will form a kind of atmosphere about it. This atmosphere will remain for a few seconds, and afterwards, beginning from the bottom, will gradually vanish, until at last, entirely departing from the electrified body, it goes off in a slender column, that soon rarefies, and diffuses itself into a considerable space.

This

This experiment will not succeed, unless it be made in very dry weather, and in a room where the air is not agitated. Care must also be taken, that, in blowing out the taper, and presenting it to the electrified body, the air be disturbed as little as possible.

This phenomenon has induced some philosophers to suppose, that the Electricity of an electrified body resided about it, *i. e.* rested upon its surface like an atmosphere; which, they thought, was made very evident by the smoke. But this appearance, when duly considered, is far from proving any such electric atmosphere; and the cause of it may be very easily explained in the following manner:—The smoke is attracted by the electrified body in the same manner, and for the same reason, that other bodies are attracted by it. It remains suspended about that body, and cannot all come into contact with its surface, on account of the elasticity of its particles. It remains so long suspended about the electrified body, and is not immediately repelled, because it is a
bad

bad Conductor, and acquires Electricity very slowly; but, having acquired a sufficient quantity of Electricity, it begins to quit the electrified body, and, ascending in the air, extends itself into a large space, in consequence of the repulsion existing between its own electrified particles.

EXPERIMENT VII.
To shew that Metals conduct the electric Fluid through their Substance.

Take a wire of any kind of metal, and cover part of it with some electric substance, as rosin, sealing-wax, &c. then discharge a jar through it, and it will be found, that it conducts as well with as without the electric coating. This proves that the electric fluid passes through the substance of the metal, and not over its surface.



EXPERIMENT VIII.

The electrified Cup and Chain.

Insulate a metallic cup, or any other concave piece of metal, and place within it a pretty long metallic chain, having a silk thread tied to one of its ends. To the handle of the cup, or to a wire proceeding from it, suspend a cork-ball electrometer; then electrify the cup, by giving it a spark with the knob of a charged phial, and the balls of the electrometer will immediately diverge. If, in this situation, one end of the chain be gradually raised up above the top of the cup, &c. by the silk thread, while the lower end of the chain remains in it, the balls of the electrometer will converge a little, and more or less in proportion to the elevation of the chain above the top of the vessel; which proves that the Electricity of the cup and chain together is more dense when these bodies are in a compact, than when they are in a more extended form. A more easy method of

shewing this property of Electricity, is that used by T. RONAYNE, Esq; which is as follows:—He excites a long slip of white flannel, or a silk ribband, by rubbing it with his fingers; then, by applying his hand to it, takes off as many sparks as the excited electric will give; but when the flannel, &c. has lost the power of giving any more sparks in this manner, he doubles, or rolls it up; by which operation the contracted flannel, &c. appears so strongly electrical, that it not only gives sparks to the hand brought near, but it throws out spontaneous brushes of light, which appear very beautiful in the dark.

EXPERIMENT IX.

To shew the Course of the electric Fluid by the Flame of a Wax-taper.

Fix at that extremity of the prime Conductor which is the remotest from the machine, a brass rod six inches long, having on its extremity a brass ball about three-fourths of an inch in diameter, and let the winch of the machine be moved.

If

If in this situation the flame of a wax-taper be presented to the above-mentioned brass ball, it will be blown almost horizontally, and in a direction from the ball; that is, in the direction of the electric fluid. If a wire, with a like ball, be fixed to the insulated rubber, the flame of a wax-taper, presented to this ball, will be blown also in the direction of the electric fluid; that is, it will be blown upon the ball, shewing the true course of the electric fluid in a very simple and convincing manner.

EXPERIMENT X.

To shew the electric Attraction and Repulsion by the electric Light.

Fix a pointed wire upon the prime Conductor with the point outward, and another like wire upon the insulated rubber; then let the winch of the machine be turned, and the points of both wires will appear illuminated, viz. the former with a brush, and the latter with a star. In this situation, take an excited glass tube, and bring it

it sideway of the point of the wire fixed upon the prime Conductor, and you will see that the brush of rays issuing from the point, is turned sideway, *i. e.* is repelled by the atmosphere of the tube; and if the excited tube be held just opposite to the point, the brush will entirely vanish, because both the tube and the point are electrified positively. If the excited tube be brought near the point of the wire fixed upon the rubber, the star upon it will turn itself towards the tube; for this wire, being electrified negatively, will attract the electric fluid of the excited tube.

If this experiment be repeated with an excited stick of sealing-wax, or any other electric negatively electrified, instead of the glass tube, it will be found that the brush proceeding from the wire fixed upon the prime Conductor, will turn itself towards the excited wax, &c. and the star upon the point of the wire negatively electrified, will be diverted from it, or entirely suppressed, if the excited stick of sealing-wax be brought just opposite to the point.

EXPERIMENT

EXPERIMENT XI.

*A curious Method of shewing the Penetrability
of electric Light.*

Let the extremities of two wires, one of which proceeds from the outside of a charged jar, and another from one branch of the discharging rod, be laid on a table at about $\frac{1}{2}$ of an inch distance of each other; then put the thumb just upon that interruption, pressing it flat down. This done, bring the discharging rod in contact with the knob of the jar, and on making the discharge, the spark which necessarily happens under the thumb will illuminate it in such a manner, that the bone, and the principal blood-vessels, may be easily discovered in it.

In this experiment the operator needs not be afraid of receiving a shock; for the discharge of the jar passes from wire to wire, and only affects the thumb with a sort of tremor, which is far from being painful.

EXPERIMENT

EXPERIMENT XII.

To illuminate a Quantity of Water by the Discharge of a Jar.

Let every thing be disposed in the manner mentioned in the preceding experiment, excepting only that, instead of the thumb, a large clear glass decanter full of water, having a flat bottom, be laid just over the interruption of the circuit. Then, on making the discharge, the water will be seen all illuminated to the very top of the decanter.

EXPERIMENT XIII.

To illuminate Ivory, Wood, &c.

Place a ball, or a thick piece of ivory, between the extremities of the wires of the universal discharger, and by connecting one of the wires with the outside, and the other with the inside of a charged electric jar, pass the shock through the said ball, and it will appear all illuminated.

If

If box wood be used instead of ivory, it will appear illuminated with yellow, red, purple, or crimson colour.—Other sorts of wood exhibit other shades of red or yellow, and sometimes green; which varieties of colour seem to depend mostly on the compactness of the wood, and on its degree of dryness.

EXPERIMENT XIV.

The electrified Capillary Syphon.

Let a small bucket of metal, full of water, be suspended from the prime Conductor, and put in it a glass syphon of so narrow an extremity, as the water will just drop from it. If in this disposition of the apparatus the winch of the machine be turned, the water, which, when not electrified, only dropt from the extremity of the syphon, will now run in a full stream, which will even be subdivided into other smaller streams; and if the experiment be made in the dark, it will appear beautifully illuminated.

EXPERIMENT XV.

The electrified Bells.

Fig. 10 of Plate II. represents an instrument having three bells, which are caused to ring by the power of electric attraction and repulsion. B is a brass piece furnished with a hook, by which it may be suspended from the rod proceeding from the extremity of the prime Conductor A. The two bells, C and E, are suspended by brass chains; but the middle bell D, and the two small brass clappers between C D, and D E, are suspended by silk threads. From the concave part of the bell D, a brass chain proceeds, which falls upon the table, and has a silk thread F at its extremity. The apparatus being disposed as in the figure, if the cylinder of the machine be turned, the clappers will fly from bell to bell with a very quick motion, and the bells will ring as long as they are kept electrified.

The two bells, C and E, being suspended by brass chains, are first electrified; hence they attract the clappers, communicate to them a little Electricity, and repel them to the unelectrified bell D, upon which the clappers deposit their Electricity, and then run again to the bells C E, from which they acquire more Electricity, &c. If by holding the silk thread F, the chain of the middle bell be raised from the table, the bells, after ringing a little while, will stop, because the bell D remaining insulated, will soon become as strongly electrified as either of the other two bells; in which case the clappers, having no opportunity of depositing the Electricity that they acquire from the bells C, E, must consequently stop.

If this experiment be made in the dark, sparks will be seen between the clappers and the bells.

The experiment will have a better effect, if, instead of keeping the machine in motion, a charged jar be set with its knob in contact with the prime Conductor.

EXPERIMENT XVI.

The Spider seemingly animated by Electricity.

Fig. 9 of Plate II. represents an electric jar, having a wire CDE fastened on its outside, which is bended so as to have its knob E as high as the knob A. B is a spider made of cork, with a few short threads run through it, to represent its legs. This spider is fastened at the end of a silk thread, proceeding from the ceiling of the room, or from any other support, so that the spider may hang mid-way between the two knobs A, E, when the jar is not charged. Let the place of the jar upon the table be marked; then charge the jar by bringing its knob A in contact with the prime Conductor, and replace it in its marked place. The spider will now begin to move from knob to knob, and continue this motion for a considerable time, sometimes for several hours.

The inside of the jar being charged positively, the spider is attracted by the knob A, which

A, which communicates to it a small quantity of Electricity; the spider then becoming possessed of the same Electricity with the knob A, is repelled by it, and runs to the knob E, where it discharges its Electricity, and is then again attracted by the knob A, and so on. In this manner the jar is gradually discharged; and when the discharge is nearly completed, the spider finishes its motion.

EXPERIMENT XVII.

The Spiral Tube.

Fig. 13 of Plate II. represents an instrument composed of two glass tubes C D, one within another, and closed with two knobbed brass caps, A and B. The innermost of these tubes has a spiral row of small round pieces of tin-foil, stuck upon its outside surface, and lying at about one thirtieth of an inch from each other. If this instrument be held by one of its extremities, and its other extremity be presented to the prime Conductor, every spark that it receives from the prime Conductor, will

cause small sparks to appear between all the round pieces of tin-foil stuck upon the innermost tube, which in the dark affords a pleasing spectacle; the instrument appearing encompassed by a spiral line of fire.

The small round pieces of tin-foil are sometimes stuck upon a flat piece of glass, ABCD, fig. 12, so as to represent curve lines, flowers, letters, &c. and they are illuminated after the same manner as the spiral tube; *i. e.* by holding the extremity C, or B, in the hand, and presenting the other extremity to the prime Conductor, when the machine is in motion.

EXPERIMENT XVIII.

To make Holes through a Glass Tube by means of Electric Sparks.

Let a glass tube of any diameter, and about five or six inches length, be closed hermetically, or by means of sealing-wax, at one end, and fill about half of it with olive oil; then stop the aperture of it with a cork, and let a wire pass through the cork, and come so far within the tube, as to have its extremity

mity below the surface of the oil. This end of the wire must touch the surface of the glass, for which purpose it must be bent nearly at right angles, which may be easily done before the cork is put upon the tube. Things being thus prepared, bend into a ring the other extremity of the wire, and suspend it, with the tube hanging to it, to the wire at the end of the Conductor. Then work the machine, and bring the knuckle of a finger or the knob of a wire near the outside of the tube, just opposite the extremity of the wire; the consequence of which will be, that a spark will happen between the wire and the knuckle, which makes a hole through the glass.—By turning the wire about, or raising and lowering it, many holes may be successively made in the same tube, after the manner above described.

In this experiment it is very remarkable, that so small a power as a simple electric spark should perforate a hole through so hard a substance as glass; and sometimes the thickness of the glass has been nearly a quarter of an inch.

EXPERIMENT XIX.

To cause the Quicksilver to rise in a Thermometer by means of Electricity.

Fix a wooden ball to the wire that proceeds from the extremity of the prime Conductor, and place another like wooden ball on a wire or other Conductor that communicates with the earth, at about half an inch distance from the other ball; in which situation, it is clear that, when the machine is in action, a stream of electric fluid will pass from one ball to the other. Now if you place the bulb of a mercurial thermometer in that stream, viz. between the two balls, you will find that the quicksilver in it will be gradually raised by the action of the stream; and if the machine is worked for some time, the mercury will be raised several degrees above its former station.

N. B. For this experiment, the bulb of the thermometer must be quite detached from the scale, so that the scale may begin
at

at least three inches above it. The experiment answers best when the balls are of soft wood.

EXPERIMENT XX.

To let Sealing-Wax be spun into fine Threads by means of Electricity.

Stick a small bit of sealing-wax on the extremity of a wire, and warm it so as to be ready to drop; in the mean time let the electrical machine be worked; then stop the motion of the machine, and at the same time bring the hot sealing-wax within four or five inches of the prime Conductor, moving it about in a winding direction, and you will find that the sealing-wax throws several exceedingly fine threads to the prime Conductor, which appear like red wool.

This experiment answers best when the Conductor is covered with varnish.

EXPERIMENT XXI.

The dancing Balls.

Fix a pointed wire upon the prime Conductor, with the point outward; then take a glass tumbler, grasp it with your hands, and present its inside surface to the point of the wire upon the prime Conductor, while the machine is in motion: the glass in this manner will soon become charged; for its inside surface acquires the Electricity from the point, and its outside loses its natural quantity of electric fluid through the hands, which serve as a coating.—This done, put a few pith-balls upon the table, and cover them with this charged glass tumbler. The balls will immediately begin to leap up along the sides of the glass, as represented fig. 15, Plate II. and will continue their motion for a considerable time.

In this experiment the pith-balls are attracted and repelled by the electric fluid superinduced upon the inside surface of the glass,

glass, which they gradually conduct to the table, or other conducting body upon which the glass is set; at the same time that the outward surface of the glass acquires the electric fluid from the contiguous air.

EXPERIMENT XXII.

To promote the Evaporation of Fluids, by means of Electricity.

Take two equal pewter plates, and pour in each of them an equal quantity of water, just enough to cover their bottoms, and with the help of a pair of scales let them be made equal in weight. This done, put one of the plates upon an insulated stool, communicating with the prime Conductor of the electrical machine, and situate the other plate in some other part of the room, where it may be in an equal degree of heat, and equally exposed to the air as the other plate, but only out of the influence of Electricity. Let now the machine be put in action, so as to keep the prime Conductor, and the plate connected with it, strongly electrified for about half an hour or longer. Then stop the machine,

chine, and weigh both the plates; it will be found, that the plate which has been electrified is the lighter: hence it is plain, that the electrization has promoted the evaporation of the water contained in it.

The same experiment may also be made with fruit, with animals, with plants, and in short, with any thing that is actually evaporating; but in some such cases, the electrization should be continued much longer; and also other circumstances ought to be taken into account, in order to render the effect of Electricity both sensible and certain. This experiment is also attended with the same effect, whether the electrization is positive or negative; hence we have another reason to disbelieve that negative electrization produces any effects upon the human body, different from the positive. One Mr. KOESTLIN, who a few years ago published a dissertation on the effects of Electricity upon some organic bodies, pretended to have found, that both animal and vegetable life were retarded by negative electrification; but I do not know whether the experiment was ever repeated by any body else,

else. The oddity and diversity of effects arising from experiments apparently similar, are such, that no person, conversant with experimental philosophy, should positively affirm any new natural law, that is indicated by a few facts, which are mostly of a dubious nature; especially when many other considerations seem to shew the improbability of the assertion.

EXPERIMENT XXIII.

To shew that the Fluids of the Human Body are better Conductors of Electricity than Water.

Take a glass tube about one-fortieth of an inch in diameter, and nearly six inches long, or rather two such tubes, exactly equal in length and diameter; and holding one of them with one extremity in water, let it be filled with that fluid. The water will soon fill the tube, in virtue of the capillary attraction; especially if the tube be held inclined to the surface of the water. After the same manner let the other tube be filled with blood, or some other fluid of the human body. Now let an electric jar be charged, and the circuit through which the jar is to be

be discharged, let it be formed of one of these tubes; to the extremities of which slender wires may be fitted so as just to touch the fluid contained in it, and also the arms of a person that is desirous of trying the experiment. In this manner, if the discharge of the jar be made several times, alternately changing the glass tube, *viz.* using once that filled with water, then the other filled with blood, and so on; it will be found that the shock is felt more sensibly when the glass tube filled with any fluid of the human body forms part of the circuit, than when the tube filled with water is used.

The person who tries this experiment need not be afraid of the shocks, because their force is much weakened by going through the fluid contained in the glass tube. Besides, the strength of the shocks should not be greater than may be just felt. It is only necessary to charge the jar always equally high, which is easily done by means of Mr. LANE's Electrometer, described in the preceding pages.

After

After the like manner the degree of conducting power of various substances may be ascertained. Thus it may be observed, that sea-water conducts better than fresh water, and that common fresh water conducts better than distilled water. The conducting power of some powders may be also tried in this manner.

EXPERIMENT XXIV.

To break small Glass Tubes by means of an electric Shock.

Let some glass tubes be drawn with the help of a blow-pipe, nearly in the shape represented by A B, fig. 9, Pl. II. viz. narrow in the middle and larger towards their extremities. The diameter of the middle part should not exceed one-twentieth part of an inch. Fill one of these tubes with water, after the manner described in the preceding experiment, and insert two slender wires through both apertures, the extremities of which, in the tube, should come within about one tenth of an inch of each other.— This done, let the discharge of an electric jar be made through this tube, viz. by connecting

necting the ring of the wire A with the outside of the jar, and the ring of the wire B with the inside of the said jar, and the tube will be broke with considerable violence. The same effect is produced when the tube is filled with any other liquor instead of water.

If the extremities of the wires within the tube are put so far from each other, as to exceed the distance at which the charge of the jar can leap in the form of a spark, then the glass tubes will not be broke.

By this experiment we can hardly deduce any instruction relative to the sensation of the shock perceived by a person, who forms the circuit in the discharge of an electric jar; for we learn by the experiment, that except any spark happens within the water, the finest and brittlest tube is not broke; and therefore we may conclude, that the concussion given to the tube by the shock, when the extremities of the wires within it are considerably far from each other, is very little, if at all sensible.—Farther, it seems plain, that if instead of one tube, the discharge of the jar was made through one hundred

hundred or one thousand tubes, the impulse of the shock would be proportionably lessened; and indeed we can hardly form any idea of the smallness of its power in that case. How happens it then that a very small shock sent across the arms of a man, which shock, we may reasonably suppose, does not occasion any spark within the vessels of the body, is sensibly felt, and produces an involuntary motion, when it passes through innumerable vessels filled with fluids, which are far better conductors than water?

The substance of the vessels of the human body is certainly a less good conductor than the fluids contained in those vessels; but it can hardly be suspected, that the electric fluid occasions the involuntary motion, &c. by going through that substance rather than through the fluids, which are much better conductors. Perhaps that sudden involuntary motion is produced by the electric fluid acting upon the nerves. But it seems that, independent of the already known parts of the human body, there is some other principle that accompanies the life of an animal, which is in a certain man-

ner a conductor of electricity, and whose action ceases as soon as the animal becomes extinct. It has been remarked in several instances, that if an electric shock passes through a given part of a living animal, the same shock, after the animal is dead, will be visibly transmitted over the surface of the same part, but not through it.

EXPERIMENT XXV.

To crystallize Oil of Tartar by means of Electric Sparks,

Take a glass tube about four inches long, and about one quarter of an inch in diameter, open at both ends, and moisten the inside of it with oil of tartar *per deliquium*; then adapt two corks to the extremities of this tube, and introduce a wire through each of them. The extremities of these wires within the tube should be about three quarters or one inch from one another. This done, connect one of the wires with the outside coating of a pretty large electric jar, and the other wire with the discharging electrometer;

electrometer ; then let the jar be discharged several times through the tube ; and it will be often found, that the oil of tartar upon the inside surface of the tube, gives manifest signs of crystallization. Now by experiments similar to this, some ingenious persons have pretended to shew, that the electric fluid contains an acid, which combining with the oil of tartar, neutralizes it, and occasions the crystallization.—It has even been said, that the phenomena of electricity are the effects of two principles, *viz.* an acid, which constitutes the positive, and an alkali, which constitutes the negative electricity. It would be useless to endeavour to refute such an hypothesis, when a very little acquaintance with the subject is sufficient to manifest its absurdity. The crystallization has been with more justice attributed to a quantity of fixed air generated by the action of the shocks on the common air within the tube.



C H A P. XII.

*Further Properties of the Leyden Phial, or
charged Electrics.*

TH E properties of charged electrics, plain as they may appear at first sight, and conformable to the commonly-established theory of Electricity, are yet, when attentively considered, far from being intirely understood, so as to require no further experiments, or leave no doubt in the mind of the speculative Electrician. The first question, that naturally occurs; in considering a charged phial, is, Where does the superinduced electric fluid reside? — Is it lodged in the substance of the glass, or in the air contiguous to the surface of the phial? In the first case, if the electric fluid penetrates a certain quantity of the substance of the glass, it follows, that a glass plate may be given so thin, that the electric fluid may freely pervade its substance.

stance *. If such a plate can be made, it will be easy, from thence, to determine how far the electric fluid can penetrate the substance of the glass, when charged in the usual manner. In the second case, if the electric fluid resides in the air contiguous to the glass, it must repel that air, *i. e.* a glass bottle should contain less air when charged, than when in its natural state; but this is contrary to experience.

The late Mr. CANTON charged some thin glass balls of about an inch and a half in diameter, having tubes of about nine inches in length, and afterwards sealed them hermetically. If these balls, when they were cold, were presented to an electrometer, they shewed no sign of Electricity; but if they were kept a little while near the fire, they then appeared strongly electrical, and possessed of that kind of Electricity with which their inside had been charged.

* I have often blown glass balls so thin, that their substance was less than one six-hundredth part of an inch, and have always observed, that they were capable of receiving a charge, which they retained for a considerable time, if they were not made very hot.

Mr. CANTON discovered farther, that if these balls are kept under water, they retain their virtue for a considerable time, even for several years; but if they are often used, their power is soon exhausted. It is obvious to remark, that the Electricity, which appears upon the outside of these balls, when they are rendered hot, *i. e.* when the glass is rendered a Conductor by the heat, is not that Electricity, which properly constitutes the charge, but the superfluous Electricity of their inside*.

As for the Electricity, which constitutes the charge, it being just sufficient to balance the contrary Electricity of the oppo-

* If a charged jar be insulated, and discharged with an insulated discharging rod, after the discharge both the sides of the jar, together with the discharging rod, will be found possessed of the Electricity contrary to the Electricity of that side of the jar, which was touched last before the discharge; which shows that one side of a charged electric may contain a greater quantity of Electricity than that, which is sufficient to balance the contrary Electricity of the opposite side. This redundant Electricity should be carefully considered in performing experiments of a delicate nature.

sive surface of the glass, it will lose its power as soon as it is arrived to that surface, which in the case of the above-mentioned balls, it actually reaches, before it can act upon the electrometer.

The most remarkable phenomena produced by charged electrics, are exhibited with flat plates of glass, jointly charged, like a single coated plate. If two glass plates, having plain surfaces, be placed one upon the other, and their outward surfaces be coated with tin-foil, in the usual manner of coating a single plate for the Leyden experiment, and then be charged, by presenting one coating to the prime Conductor, and communicating the other with the earth, the plates (which we shall call A, and B) after having been charged, will adhere very firmly to one another, and if separated, A, *viz.* that, whose coating was presented to the prime Conductor, will appear positive on both sides, and B negative on both sides. If these plates are laid in contact as before they were charged, and are discharged by making a communication between the two coated sides, they will be found

found still to adhere to one another after the discharge; and if separated, they will appear still electrified, but with this remarkable difference, *viz.* that now A is negative on both sides, and B positive on both sides. If these plates, after being discharged, be separated in the dark, flashes of light are perceivable between their internal surfaces. By laying the plates together, touching their coatings, and separating them successively, the flashes may be observed for a considerable number of times, diminishing by degrees, until they quite vanish.

Father BECCARIA explains these, and other similar phenomena of charged as well as of excited electrics, by the following principle, which he distinguishes by the name of *vindicating Electricity*.—When two bodies, either a Conductor and an electrified electric, or two contrarily and equally electrified electrics, are joined together, they adhere to each other, and their Electricities disappear; but as soon as they are separated, the electrics recover their Electricities*.

* See BECCARIA's Artificial Electricity, Part II. Sec. VI.

How far this principle can be of use to explain the phenomena of charged glass, &c. I will not take upon me to determine. It would exceed too far the limits of my work, if I were to enumerate and account for all the particulars minutely. When the principle is expressed, the ingenious reader may easily apply it to explain the effects. I shall only mention an observation of Mr. HENLY, relative to this subject, which seems not conformable to Father BECCARIA's theory; and with that I shall conclude this Part of my work. Says Mr. HENLY, in one of his papers presented to the Royal Society, in which he describes the above-mentioned experiments of the two glass plates: —

“ Crown-glass, that is, the glass commonly
 “ used for sash-windows, though so much
 “ thinner, succeeds in this experiment as
 “ well as the plate-glass; but what is very
 “ remarkable, the Dutch plates, when
 “ treated in the same manner, have each a
 “ positive and negative surface, and the
 “ Electricity of both surfaces of both plates
 “ is exchanged for the contrary Electricity
 “ in the discharge. If a clean, dry, uncoated
 “ plate of looking-glass be placed between

B b

“ the

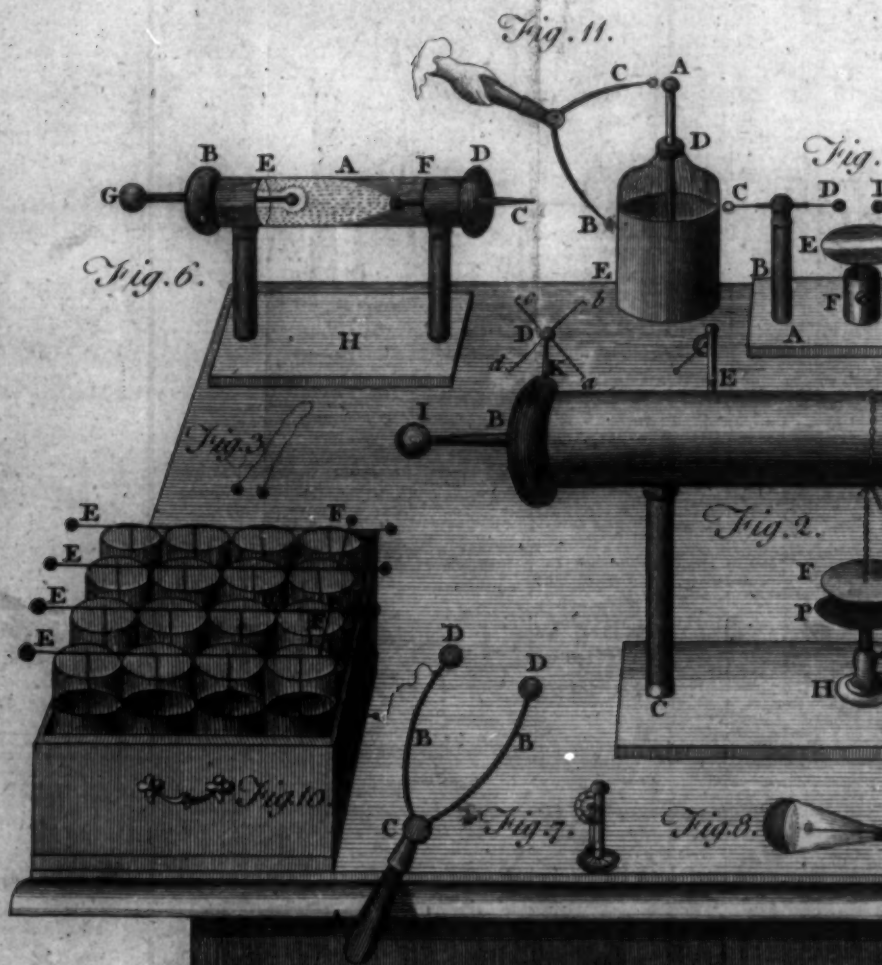
“ the coated looking-glass plates, or between the plates of crown-glass, it appears, after charging, to be negatively electrified on both sides; but if it be placed between the Dutch plates, it acquires, like them, a positive Electricity on one surface, and a negative Electricity on the other.”

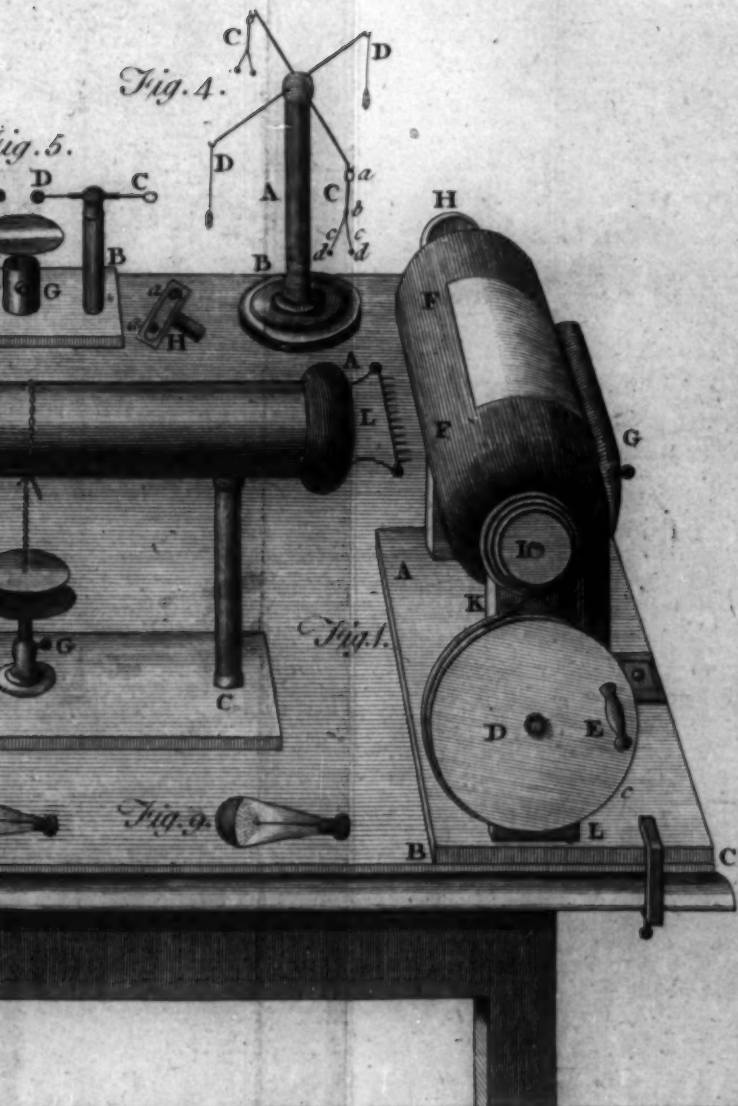
In another paper Mr. HENLY further observes, that if the Dutch plates are separated immediately after being charged, they will then act like two plates of looking-glass, *i. e.* one of them will be positive, and the other negative on both sides; but if a little time be allowed before the plates be separated, the experiment will constantly succeed as above*.

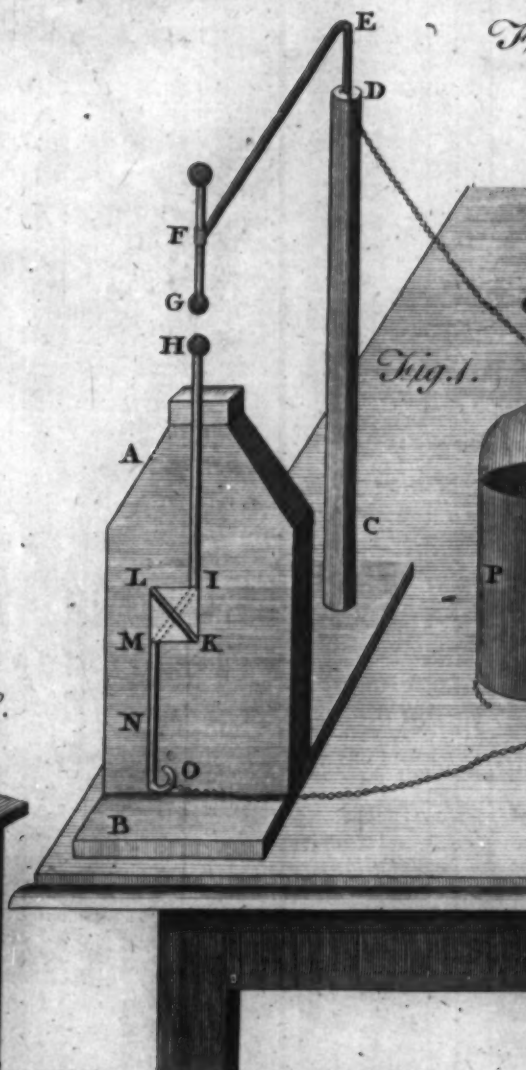
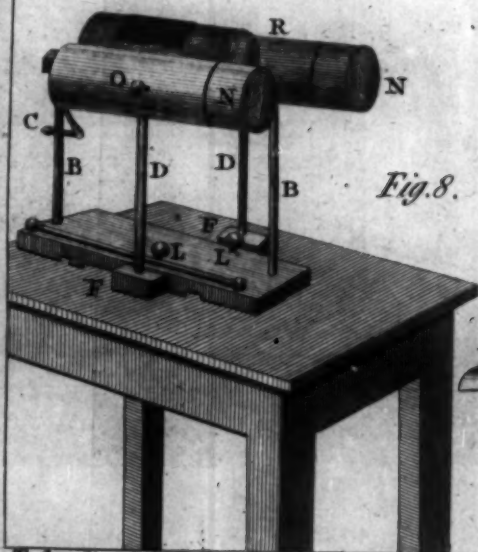
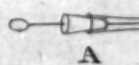
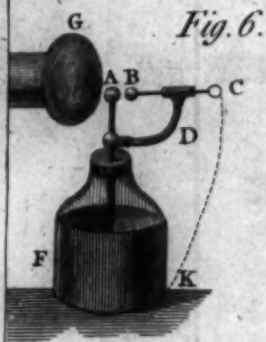
* To this edition, a dissertation on the *vindicating Electricity* has been added in the Appendix; which will shew, by plain experiments, this wonderful property of glass, &c. whilst this chapter has been here reprinted just as it was published in the first edition.

THE END OF VOL. I.









T. Cavallo del:

Fig. 9.

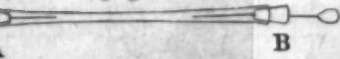


Fig. 2.

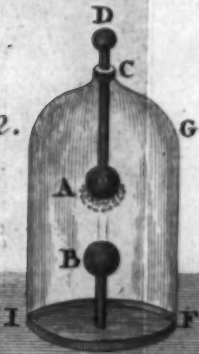


Fig. 3.



Fig. 9.

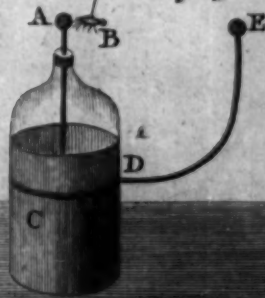


Fig. 15.



Fig. 11.

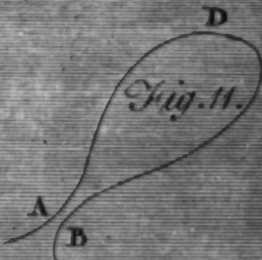


Fig. 12.



Fig. 13.



Fig. 10.

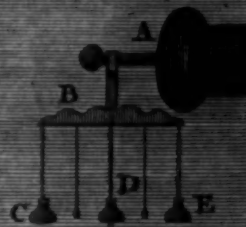


Fig. 14.

